UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

META PLATFORMS, INC.
Petitioner

v.

THALES VISIONIX, INC.,
Patent Owner

U.S. PATENT NO. 6,922,632

IPR2022-1304

PETITION FOR *INTER PARTES* REVIEW
UNDER 35 U.S.C. §312 AND 37 C.F.R. §42.104

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LIST OF EXHIBITS

1001	U.S. Patent No. 6,922,632
1002	File History of U.S. Patent No. 6,922,632
1003	U.S. Patent No. 7,725,253
1004	File History of U.S. Patent No. 7,725,253
1005	Declaration of Dr. Ulrich Neumann in Support of *Inter Partes Review* of U.S. Patent No. 6,922,632
1006	*Curriculum Vitae* of Dr. Ulrich Neumann
1007	Welch, G. et al., "High-Performance Wide-Area Optical Tracking" (2001)
1008	Welch, G. et al., "SCAAT: Incremental Tracking with Incomplete Information" (1997)
1009	Welch G. "SCAAT: Incremental Tracking with Incomplete Information" PhD Thesis, University of North Carolina (1996)
1010	U.S. Patent No. 5,615,132
1011	U.S. Patent No. 5,307,289
1012	Gentex's Amended Preliminary Infringement Contentions and corresponding Exhibits 4 and 5 ('632 and '253 infringement charts)
1013	Azuma, R. "Predictive Tracking for Augmented Reality" PhD Thesis, University of North Carolina (1995)
1014	You, S. and Neumann, U. "Orientation Tracking for Outdoor Augmented Reality Registration." (1999)

1015	Carlson, Neal A. and Berarducci, Michael P. “Federated Kalman Filter Simulation Results.” Navigation. Vol. 41, Issue 3 at 297-322. (Fall 1994)
1016	Reitmayr, Gerhard and Schmalstieg. “An Open Software Architecture for Virtual Reality Interaction” VRST ’01 (November 2001)
1017	Barfield, W. “Fundamentals of Wearable Computers and Augmented Reality” (2001)
1018	Declaration of Rachel J. Watters regarding Welch, G. et al., “High-Performance Wide-Area Optical Tracking” (2001)
1019	Declaration of Scott Delman regarding Welch, G. et al., “SCAAT: Incremental Tracking with Incomplete Information” (1997)
1020	Declaration of Dr. James L. Mullins regarding Welch G. “SCAAT: Incremental Tracking with Incomplete Information” PhD Thesis, University of North Carolina (1996)
1021	Declaration of Scott Delman regarding Reitmayr, Gerhard and Schmalstieg. “An Open Software Architecture for Virtual Reality Interaction” VRST ’01 (November 2001)
1022	U.S. Patent No. 5,807,284
1023	U.S. Patent No. 5,991,085
1024	Chen, Steven C. and Lee, Kang. “A mixed-mode smart transducer interface for sensors and actuators”, Sound & Vibration, 32(4), 24-27 (April 1998)
1025	Hoff, William and Vincent, Tyrone. “Analysis of Head Pose Accuracy in Augmented Reality”, IEEE Transactions on Visualization and Computer Graphics, Vol. 6, Issue 4, October - December 2000.

1026	Zetu, Dan et al., "Extended-Range Hybrid Tracker and Applications to Motion and Camera Tracking in Manufacturing Systems," IEEE Transactions on Robotics and Automation, Vol. 16, Issue 3, June 2000
1027	Declaration of Rachel J. Watters regarding Chen, Steven C. and Lee, Kang. "A mixed-mode smart transducer interface for sensors and actuators." Sound & Vibration, 32(4), 24-27 (April 1998)
1028	Declaration of Gordon MacPherson regarding Hoff, William and Vincent, Tyrone. "Analysis of Head Pose Accuracy in Augmented Reality", IEEE Transactions on Visualization and Computer Graphics, Vol. 6, Issue 4, October - December 2000.
1029	Declaration of Gordon MacPherson regarding Zetu, Dan et al., "Extended-Range Hybrid Tracker and Applications to Motion and Camera Tracking in Manufacturing Systems," IEEE Transactions on Robotics and Automation, Vol. 16, Issue 3, June 2000
1030	U.S. Patent No. 5,592,401

Petitioner Meta Platforms, Inc. ("Meta" or "Petitioner") requests *inter partes* review ("IPR") of claims 1-9, 11-29, and 66-69 (the "Challenged Claims") of U.S. Patent No. 6,922,632 (Ex.1001, "the '632 Patent").

I. INTRODUCTION

Before the '632 Patent's earliest priority date, it was well known that any computer-implemented method for object tracking required a set of sensors and an algorithm for updating a state of the tracked object in light of the sensor output. For example, the use of Kalman filters to receive sensor measurement information and update the state estimate of a tracked object had been known for decades. The '632 Patent, however, claims that basic functionality in its independent claims, and then claims obvious variations of that functionality in the dependent claims. Because the purportedly novel aspects of the '632 Patent were well known in the prior art and practiced by persons of skill in the art before the claimed priority date, Petitioner respectfully requests that the Challenged Claims be canceled as invalid.

II. MANDATORY NOTICES

A. Real Party-In-Interest

Petitioner identifies the following real parties-in-interest: Meta Platforms, Inc. and Meta Platforms Technologies, LLC.

B. Related Matters

Gentex Corporation ("Gentex") and Indigo Technologies, LLC ("Indigo"), the current and former licensees of the '632 Patent, have asserted the '632 Patent in

Gentex Corporation et al. v. Facebook, Inc. et al., No. 6:21-cv-00755-ADA (W.D. Tex.) (the "Texas Litigation"), which was thereafter transferred to the Northern District of California, No. 5:22-cv-03892 (the "California Litigation"). Thales Visionix, Inc. ("Thales Visionix" or "Patent Owner") is named as an involuntary plaintiff in these litigations.

C. Counsel and Service Information

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D. 37 C.F.R. §42.8(b)(4): Service Information

Meta concurrently submits a Power of Attorney, 37 C.F.R. §42.10(b), and consents to electronic service directed to the following email address: Meta-Thales-IPR@kirkland.com.

III. PAYMENT OF FEES UNDER 37 C.F.R. §42.103

The undersigned authorizes the Office to charge the fee set forth in 37 C.F.R. §42.15(a)(1) for this Petition to Deposit Account No. 506092. Review of 32 claims is requested. The undersigned further authorizes payment for any additional fees that may be due in connection with this Petition to be charged to the above-referenced deposit account.

IV. CERTIFICATION OF GROUNDS FOR STANDING

Petitioner certifies pursuant to Rule 42.104(a) that the ’632 Patent is available for IPR and that Petitioner is not barred or estopped from requesting an IPR of the Challenged Claims on the grounds identified in this Petition. Petitioner certifies: (1) Petitioner is not the owner of the ’632 Patent; (2) Petitioner (or any real party-in-interest) has not filed a civil action challenging the validity of any claim of the ’632 Patent; (3) Petitioner files this Petition within one year of the date it was served with a complaint asserting infringement of the ’632 Patent; (4) estoppel provisions of 35 U.S.C. §315(e)(1) do not prohibit this IPR; and (5) this Petition is filed after the ’632 Patent was granted.

V. OVERVIEW OF CHALLENGE AND RELIEF REQUESTED

Petitioner challenges the patentability of the Challenged Claims of the ’632 Patent and requests that they be canceled.

A. Prior Art References

Petitioner’s challenge is based on the following prior art references:

1. **Welch, G. et al., “High-Performance Wide-Area Optical Tracking” (“Welch 2001”) (Ex.1007**, Ex.1018**)**, published February 2001 and publicly available no later than May 28, 2001, is prior art under pre-AIA 35 U.S.C. §§102(a) and 102(b).[1]

2. **Welch, G. et al., “SCAAT: Incremental Tracking with Incomplete Information” (“Welch 1997”) (Ex.1008**, Ex.1019**)**, was made publicly available on August 3, 1997 and is prior art under pre-AIA 35 U.S.C. §§102(a) and 102(b).

3. **Welch, G., “SCAAT: Incremental Tracking with Incomplete Information” PhD Thesis, University of North Carolina (“Welch Thesis”) (Ex.1009**, Ex.1020**)**, was made publicly available no later than May 24, 1997 and is prior art under pre-AIA 35 U.S.C. §§102(a) and 102(b).

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[1] Based on the claimed priority date of the ’632 Patent, Pre-AIA versions of §102(a) and §103 apply.

4. **U.S. Patent No. 5,615,132 to Horton et al. ("Horton") (Ex.1010)**, filed January 21, 1994 and issued March 25, 1997, is prior art under pre-AIA 35 U.S.C. §§102(b) and 102(e).

5. **U.S. Patent No. 5,592,401 to Kramer ("Kramer") (Ex.1030)**, issued January 7, 1997, is prior art under pre-AIA 35 U.S.C. §102(b).

6. **Chen, S., et al. "A Mixed-Mode Smart Transducer Interface for Sensors and Actuators" ("Chen") (Ex.1024,** Ex.1027**)**, published April 1998, is prior art under pre-AIA 35 U.S.C. §102(b).

The above prior art references predate the '632 Patent, which claims priority to a provisional application filed on August 9, 2002.[2]

B. Relief Requested

Petitioner requests cancellation of the Challenged Claims as unpatentable under 35 U.S.C. §103. The specific grounds of the challenge are set forth below, and are supported by the declaration of Dr. Ulrich Neumann (Ex.1005).

Ground	Claims	Proposed Statutory Rejection
I	1-9, 11-22, and 24-29	Obvious under §103 in view of Welch 2001 and Welch 1997
II	23	Obvious under §103 in view of Welch 2001, Welch 1997, and the Welch Thesis

[2] Petitioner reserves the right to challenge the August 9, 2002 priority date or any evidence of prior invention.

III	1-9, 11-24, and 28-29	Obvious under §103 in view of Horton
IV	25-27	Obvious under §103 in view of Horton and Welch 1997
V	66-68	Obvious under §103 in view of Kramer and Chen
VI	69	Obvious under §103 in view of Kramer, Chen, and Welch 2001

VI. DISCRETIONARY DENIAL IS NOT APPROPRIATE HERE

A. The ’632 Patent Has Not Been Subject to a Prior Petition

The ’632 Patent has not been subject to any prior IPR or PGR petitions.

B. Multiple Petitions are Warranted

Gentex is asserting 53 claims from the ’632 Patent in the Texas Litigation. *See* Ex.1012, 3. The Board has recognized that in such circumstances more than one petition may be necessary. *See* Trial Practice Guide Update (July 2019) . The current petition challenges 32 claims. The second petition challenges 23 claims including four independent claims. Multiple petitions are only needed due to the large number of challenged claims.

C. The Presented Grounds and Argument Are Dissimilar to the Art and Arguments Previously Presented to the Office

All factors considered by the Board under 35 U.S.C. §325(d) weigh in favor of institution. *Becton, Dickinson, & Co. v. B. Braun Melsungen AG*, IPR2017-01586, Paper 8 (P.T.A.B. Dec. 15, 2017); *see also Advanced Bionics, LLC v. MED-EL*

Elektromedizinische Geräte GmbH, IPR2019-01469, Paper 6 at 8 (P.T.A.B. Feb. 13, 2020). "[A] reference that 'was neither applied against the claims nor discussed by the Examiner' does not weigh in favor of exercising [] discretion under §325(d)." *Fasteners for Retail, Inc. v. RTC Indus., Inc.*, IPR2019-00994, Paper 9 at 7-11 (P.T.A.B. Nov. 5, 2019). None of the art presented herein was applied against the Challenged Claims or discussed by the Examiner during prosecution (nor were combinations thereof). *Bowtech, Inc. v. MCP IP, LLC*, IPR2019-00383, Paper 14 at 5 (P.T.A.B. Aug. 6, 2019).

D. Efficiency, Fairness, and the Merits Support the Exercise of the Board's Authority to Grant the Petition

A "holistic view" of the six *Fintiv* factors demonstrates that the Board should ***not*** exercise its discretion under §314(a). *Apple, Inc. v. Fintiv, Inc.*, IPR2020-00019, Paper 11 at 6 (P.T.A.B. Mar. 20, 2020) (precedential). In light of the transfer, it is a near certainty that a Final Written Decision ("FWD") in this proceeding will predate start of trial in N.D.Cal, and the district court may benefit from a FWD in IPR should the case proceed to trial. Thus, *Fintiv* Factor 2 weighs heavily in favor of institution.

FACTOR 1: Petitioner has not sought a stay, and has no knowledge regarding whether the N.D.Cal. court would grant a stay if IPR is instituted. Thus, Factor 1 is neutral. *Microchip Technology Inc. v. Bell Semiconductor, LLC*, IPR2021-00148, Paper 19 at 10 (P.T.A.B. May 14, 2021).

FACTORS 2 & 4: The Western District of Texas granted Meta's motion to transfer the Texas Litigation to the Northern District of California ("N.D.Cal."), and the case was transferred and docketed in N.D. Cal. on July 5, 2022. The resulting California Litigation was assigned to the Hon. Yvonne Rogers, and a Case Management Conference is scheduled for October 17, 2022. No trial date has been set. The median time-to-trial for patent/civil actions in N.D.Cal. is at least 30 months (January 2025). By contrast, the projected statutory deadline for a FWD is 18 months from filing (January 2024), and this date will not change. Thus, Factor 2 weighs heavily ***against*** exercising discretion to deny institution. *Slayback Pharma LLC, v. Eye Therapies, LLC*, IPR2022-00146, Paper 14 at 6 (P.T.A.B May 18, 2022). Further, because the date of the FWD will predate the district court trial, a *Sotera* stipulation should not be needed here. *Sotera Wireless, Inc. v. Masimo Corp.*, IPR2020-01019, Paper 12 (P.T.A.B. Dec. 1, 2020) at 18; *see also Sand Revolution II, LLC v. Cont'l Intermodal Grp.-Trucking LLC*, IPR2019-01393, Paper 24 at 11-12 (P.T.A.B. June 16, 2020). As detailed herein, Petitioner presents compelling evidence of unpatentability. Factor 4 is neutral.

FACTOR 3: The California Litigation has only just begun. Thus, the court has not yet invested time and resources in the parallel proceeding or the parties. Factor 3 weighs ***against*** exercising discretion to deny institution.

FACTOR 5: Petitioner was a defendant in the Texas Litigation and remains a defendant in the California Litigation. But in view of the other *Fintiv* factors—which heavily weigh ***against*** the Board's exercise of §314(a) discretion—the similarity of the parties is of limited weight here.

FACTOR 6: As set forth below, the merits of the grounds of this Petition are strong. Factor 6 weighs ***against*** the Board exercising its §314(a) discretion. *Sand Revolution*, Paper 24 at 13.

VII. OVERVIEW OF THE TECHNOLOGY

A. Head-Mounted Display in Virtual and Augmented Reality Systems

Head-mounted displays ("HMDs") are widely used in both virtual reality ("VR") and augmented reality ("AR") applications. In VR, a user is enveloped in a completely computer generated environment. HMDs provide immersive images to the user, and the user's head motion should be closely tracked to accurately reflect the user's perspective within the computer-generated environment. In AR applications, however, computer-generated images are overlaid on real scenes observed by the user through the HMD. *See* Ex.1013, Abstract. Thus, in AR, tracking of the user's head should be more accurate than for VR in order to minimize misalignment between the computer-generated image and the real scene observed by the user. *Id*.

B. Sensors for Tracking an Object in VR and AR

As acknowledged in the ’632 Background, tracking systems often use measurements from sensors to aid in determining a pose (position and orientation) of an object, such as a person’s head, as it navigates in an environment. *See* Ex.1001, 1:16-22. Various types of sensors can be used to make these measurements. For example, the ’632 Background notes that “ultrasound receivers, laser range finders, cameras, or pattern recognition devices” can be used as sensors in a tracking system. Ex.1001, 1:64-66. In an “outside-in” tracking system, the sensor is mounted in an environment and detect targets that are mounted to a tracked object. Ex.1007, 4-5. In an “inside-out” tracking system, the sensor is mounted to the tracked object and detects targets that are mounted in the surrounding environment. *Id.* Both types of systems are illustrated below, where the tracked object is the user’s head:

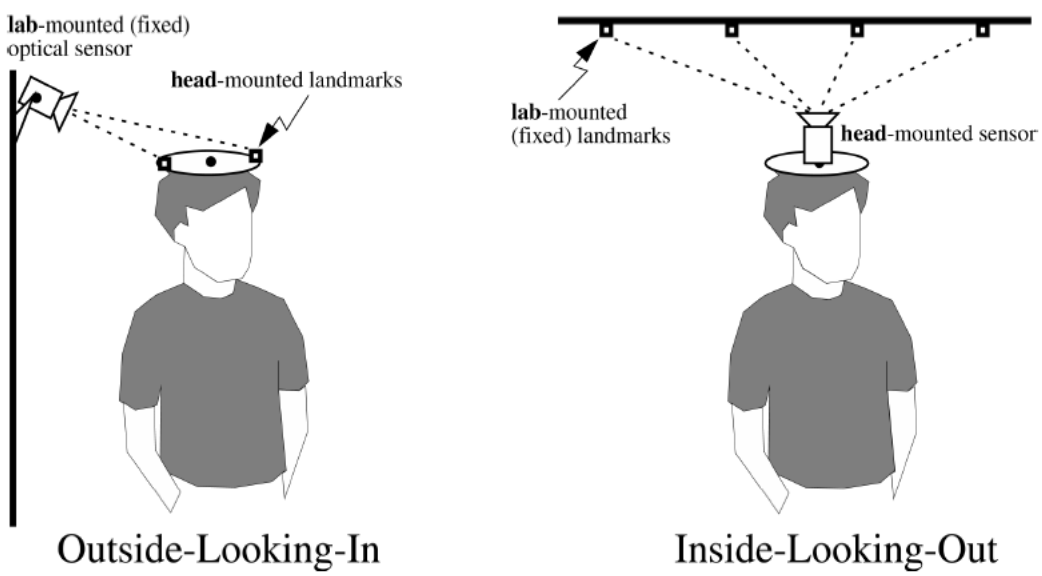


Figure 5.

Id. One known way to improve tracking accuracy is to calibrate the sensors used to determine the object's pose. While calibration is often performed off-line under controlled circumstances, goals such as flexibility, ease of use, and lower cost made the notion of self-calibration or autocalibration attractive. *See* Ex.1009 §2.5.3.

C. Using Kalman Filters to Estimate the Position and Location of a Tracked Object

Unlike analog tracking systems, which allow for continuous observations of a target, digital tracking systems introduce uncertainty because they are limited to discrete observations of a target. To deal with that uncertainty, it was well known to use an optimal estimator to predict the state of a tracked target. Ex.1009 §2.1. An optimal estimator is "a computational algorithm that processes measurements to deduce a minimum error estimate of the state of a system by utilizing: knowledge of system and measurement dynamics, assumed statistics of system noises and measurement errors, and initial condition information." *Id.*

One of the best-known optimal estimators is the Kalman filter. A Kalman filter is an "estimator that combines data from sensors and a motion model in a computationally-efficient manner. If certain assumptions hold, the Kalman filter provides estimates that are optimal in the sense of minimizing the expected mean-square error." Ex.1013, 80. The Kalman filter "assumes that the signals can be modeled by a set of variables that capture the state of the system at any time, along with a process that determines how these state variables change with time in the

absence of any inputs." *Id.*, 78. The Kalman filter then "will take the measurements and return the optimal estimate for the state variables at any desired time." *Id.*

The Kalman filter is inherently discrete because it is not derived from a continuous model, and thus is well-suited to computer-based systems. Ex.1009 §2.1; *see also* Ex.1013, 78, 83.

VIII. THE '632 PATENT

The '632 Patent issued on July 26, 2005, from U.S. Application No. 10/639,242, filed on August 11, 2003, and claims priority to Provisional Application Nos. 60/402,178 (filed August 9, 2002). The '632 Background acknowledges that a POSITA would have known at the time of the alleged invention most limitations in the Challenged Claims. Ex.1005 ¶32. For instance, the Background states that "[d]ifferent sensors may have different measurement characteristics that affect the mapping between the relative pose of a sensor and a target and the measurement values provided by the sensor. These characteristics can include uncertainty or noise characteristics of the measurement values." Ex.1001, 1:31-35.

The Background further acknowledges that Kalman filtering techniques were known "to incorporate information in sensor measurements to track the position or orientation of an object, typically also using information about the dynamic characteristics of the object," including to estimate sensor calibration parameters. *Id.*, 1:35-39, 2:12-14.

IX. PERSON OF ORDINARY SKILL IN THE ART

A POSITA at the time of the '632 Patent would have had a Bachelor's degree in Computer Science, or an equivalent field, and three to five years of experience working with computer implemented tracking systems. Additional education might compensate for less experience, and vice-versa. Ex.1005 ¶37.

X. CLAIM CONSTRUCTION

Claims only need to be construed to the extent necessary to resolve a controversy. *Nidec Motor Corp. v. Zhongshan Broad Ocean Motor Co.,* 868 F. 3d 1013, 1017 (Fed. Cir. 2017). Here, no terms need construction because the claims read on the prior art under any construction consistent with *Phillips v. AWH Corp.,* 415 F.3d 1303 (Fed. Cir. 2005) (en banc).[3]

XI. OVERVIEW OF THE PRIOR ART

A. Overview of Welch Prior Art

Welch 2001, Welch 1997, and Welch Thesis (collectively, "Welch Prior Art") describe an optical tracking system and algorithm developed over several decades at the University of North Carolina. Welch 2001 describes the "HiBall tracking system," a tracker wherein an optical sensing unit (the HiBall) is attached to a person and interacts with ceiling-mounted LEDs to track the person's movement. *See*

[3] Petitioner does not waive any arguments concerning indefiniteness, alternative claim scope, or other constructions that may be raised in the co-pending litigation.

Ex.1007, 5-6. As shown in Figure 6, the HiBall, LEDs, and a computer are connected to the "Ceiling-HiBall Interface Board (CIB)," which coordinates communication and synchronization between the computer and the HiBall/LED sensor-tracker system:

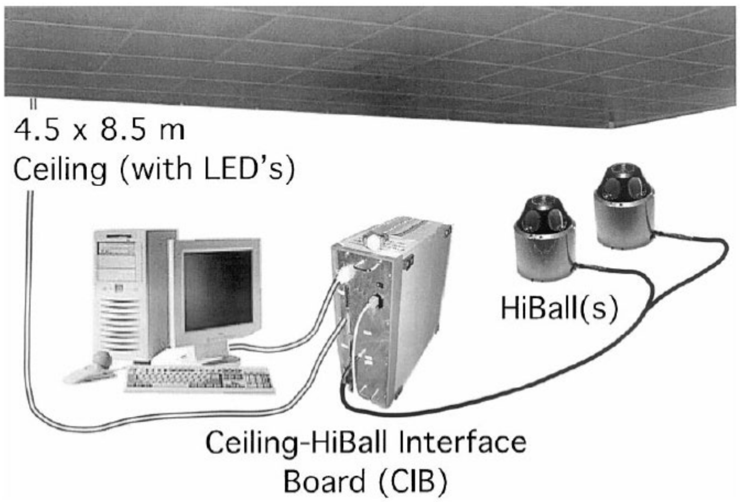


Figure 6.

Ex.1007, 5-6, Fig.6. In this system, the LEDs are flashed one at a time to be seen and measured by different views of the HiBall sensor. *Id.*, 6. To estimate the position and orientation of the tracked object (person) using these measurements, "a Kalman-filter-based prediction-correction approach known as *single-constraint-at-a-time (SCAAT)* tracking" is used. *Id.* (emphasis in original). The SCAAT model calculates the tracked object's expected position and orientation, corrects those estimates using measurement data from the sensor and a target, and recursively predicts and corrects the position and orientation using one measurement at a time. *Id.*, 12-13. Welch 1997 and Welch Thesis, which are incorporated into Welch 2001 by reference (*see*

Ex.1007, 11), describe the SCAAT tracking method and calculations in greater detail. *See generally* Ex.1008; Ex.1009.

B. Overview of Horton

Horton describes a "three-dimensional position and orientation tracking system" that tracks a moving object's six degrees of freedom (e.g., x, y, and z coordinates and roll, pitch, and yaw) using accelerometers. Ex.1010, Abstract, 2:15-20. The system includes a tracking processor that gathers position and orientation information from the accelerometers and/or other sensors and uses this data to correct and update the position and orientation estimate for the object "using a feedback or Kalman filter process." *Id.*, 2:41-44. As explained in Horton, the Kalman filter (also called a "feedback loop") "comprises reading tracking measurements [] (e.g., position, orientation, and/or velocity)" from the tracking system "and generating [] correction factors" that are used in calculating position and orientation information for the tracked object. *Id.*, 6:34-42. Horton also describes how the system is calibrated by using a Kalman filter "to solve for bias and scaling factors [] for each accelerometer." *Id.*, 5:64-6:12. This process is repeated several times. *Id.*, 6:12-14; Fig.3.

C. Overview of Kramer

Kramer describes position sensing for an object, such as a body part, using multiple sensing technologies. Ex.1030, Abstract. Kramer notes that "using

combinations of sensors, where the deficiency of one may be compensated for by the proficiency of the other, improved results as to position and/or time of the entity is obtained." *Id.*, 3:58-62, 20:23-25. Kramer contemplates combining sensors with different speeds and accuracies, e.g., "fast" sensors such as accelerometers with lower reliability combined with "slow" sensors with higher reliability. *Id.*, Abstract, 3:15-20. Such "slow" sensors include position sensors, optical tracking devices, acoustic sensors, and GPS. *Id.*, 7:36-46.

Kramer's optical tracking systems use variations of light sources/receivers mounted on the object to be tracked or at fixed positions. *Id.*, 7:47-59. *Id.* Kramer explains that the accelerometer can be used when the optical tracker is suffering from occlusion such that the position of the object being tracked cannot be uniquely determined and no position measurement is possible. *Id.*, 19:10-26.

XII. SPECIFIC GROUNDS FOR PETITION

A. <u>Ground I</u>: Claims 1-9, 11-22, and 24-29 are Rendered Obvious by Welch 2001 and Welch 1997

1. Motivation to Combine

Welch 2001 explicitly states the online measurements from the HiBall sensor system described in Section XII.A.2.c are used by the PC (estimation system) to estimate the pose of the HiBall during operation using the SCAAT tracking approach described in Welch 1997. *See* Ex.1007, 10-13. A POSITA would have understood that the SCAAT calculations performed by the PC use the online configuration

measurements as inputs to estimate the HiBall's pose, and that using these measurements as inputs constitutes "configuring the estimate system." Ex.1005 ¶56.

Specifically, a POSITA would have understood that the SCAAT tracking approach described in Welch 2001 and Welch 1997 updates the sensor state estimate according to the accepted measurement and configuration data from the sensor subsystem. Ex.1005 ¶57. Welch 2001 describes the SCAAT tracking approach as a "***recursive*** pose estimation" process. Ex.1007, 10 (emphasis added). SCAAT uses a single measurement of the sensor's state to incrementally update and improve a previous state estimate determined using equations, and the process repeats to reduce measurement noise and generate a more accurate estimate of the state of the sensor. *See id.*, 11-13 (describing SCAAT calculations that "intentionally use a single constraint per estimate"); *see also* Ex.1008 §3.1 (explaining that each updated estimate is based on a single sensor-target measurement). This approach uses a Kalman filter because the sensor measurement noise data (included in the configuration data described above) can be modeled as a normally distributed random process. Ex.1007, 11.

2. Claim 1

a. Claim 1[preamble]: "A method for tracking an object comprising:"

Both Welch 2001 and Welch 1997 (which is incorporated by reference in Welch 2001) disclose the preamble. Ex.1005 ¶58. Welch 1997 discloses a "method for tracking a user's pose (position and orientation) for interactive computer graphics." Ex.1008, Abstract. The SCAAT method predicts short-term changes in a tracked object's state using a Kalman filter, and then corrects the prediction using a measurement obtained by a sensor and a corresponding measurement model. *Id.*, Abstract, §3.

b. Claim 1[a]: "coupling a sensor subsystem to an estimation subsystem, said sensor subsystem enabling measurement related to relative locations or orientations of sensing elements;"

Welch 2001 and Welch 1997 disclose this limitation. Ex.1005 ¶¶59-61. As shown in Figure 6 below, the "Ceiling-HiBall Interface Board (CIB)" couples LED targets and HiBall sensors (the claimed "sensor subsystem") with a PC (the claimed "estimation subsystem"):

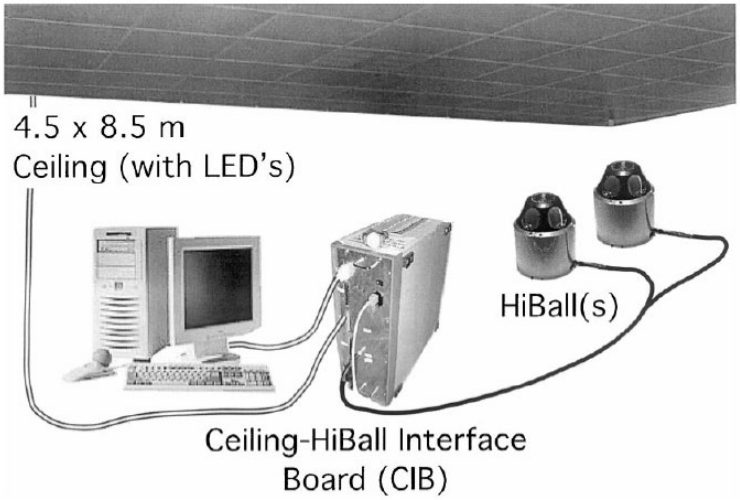


Figure 6.

Ex.1007, Fig.6. The '632 Patent explains that the "estimation subsystem" performs calculations to estimate the tracked object's position and location. *See* Ex.1001, 2:35-46; 4:11-20. The PC shown in Figure 6 of Welch 2001 is used for the same purpose—implementing the Kalman-filter-based SCAAT tracking approach to estimate the tracked object's pose. Ex.1007, 6; Ex.1008 §3.1.2 ("We are able to execute the SCAAT filter computations, with the autocalibration computations discussed in the next section…on a 200 MHz PC-compatible computer.").

Moreover, the HiBall sensors in Welch 2001 "enabl[e] measurement related to relative locations or orientations of sensing elements." The "sensing elements" include the source LEDs and the HiBall sensors. Ex.1007, Fig.6. The HiBall detects the LEDs as they flash, which enables measurement of the location and pose of the HiBall during operation by the PC. *See id.*, 10-11 (describing measurements generated by the HiBall-LED system).

c. Claim 1[b]: "accepting configuration data from the sensor subsystem;"

Welch 2001 renders this limitation obvious by describing generating and using calibration measurements from the sensor subsystem. Ex.1005 ¶¶62-63. The '632 Patent's specification describes sensor configuration data as including "a position or an orientation of a sensor" and "one or more calibration parameters of a sensor," Ex.1001, 7:15-26, both described in Welch 2001. The HiBall sensor system (the claimed "sensor subsystem") performs three measurements to determine each LED's "ideal" position coordinates. Ex.1007, 10. Further, at runtime, the HiBall sensor system is used to determine a measurement noise estimate for the Kalman filter for each LED. *Id.*

d. Claim 1[c]: "configuring the estimation system according to the accepted configuration data;"

Welch 2001 renders this limitation obvious by describing the PC (estimation subsystem) using the measurements from the HiBall sensor system described in Section XII.A.2.c "to estimate the pose of the HiBall during operation" using the SCAAT tracking approach described in Welch 1997. *See* Ex.1007, §5.3 ("Recursive Pose Estimation (SCAAT)"), 11 ("We use a Kalman filter (Kalman, 1960) to fuse the measurements into an estimate of the…pose of the HiBall."). Ex.1005 ¶¶64-65.

e. Claim 1[d]: "repeatedly updating a state estimate, including accepting measurement information from the sensor subsystem, and updating the state estimate according to the accepted configuration data and the accepted measurement data."

Welch 2001 and Welch 1997 render this limitation obvious. Ex.1005 ¶¶66-67. The '632 indicates that a state estimate can characterize an estimate of the tracked object's location. Ex.1001, 2:60-61. The "recursive pose estimation" SCAAT tracking approach described in Welch 2001 and Welch 1997 repeatedly updates both the location and orientation (i.e., pose) estimate of a HiBall according to the accepted measurement and configuration data from the sensor subsystem. Ex.1007, 10-11; Ex.1005 ¶66.

SCAAT uses a single measurement of the sensor's state to incrementally update and improve a previous state estimate determined using equations, and the process repeats to reduce measurement noise and generate a more accurate estimate of the sensor's pose. Ex.1007, 11-13; *see also* Ex.1008 §3.1.

3. Claim 2: "The method of claim 1 wherein coupling the sensor subsystem to the estimation subsystem includes coupling software modules each associated with one or more of the sensing elements."

Welch 2001 and Welch 1997 disclose this limitation. Ex.1005 ¶¶68-69. These references explain that a distinct SCAAT Kalman filter is defined for each LED and for each sensor within the HiBall—that is, for each LED and sensor, the system maintains an estimate of the 3-D position and a 3-D Kalman filter covariance.

Ex.1007, 13; *see also* Ex.1008 §3.2.1 ("For each device (source, sensor, landmark, etc.) we create a distinct device filter."). Each Kalman filter is performed in software (Ex.1007, 11-13) and constitutes a "software module" that performs the state estimate calculations, and thus using a Kalman filter with each sensing element (LED or sensor within the HiBall) satisfies this limitation. Ex.1005 ¶68.

4. Claim 3: "The method of claim 2 wherein each of the software modules provides a software interface for receiving information related to an expected sensor measurement and providing measurement information that depends on said received information."

Welch 2001 renders this limitation obvious. Ex.1005 ¶¶70-72. The HiBall sensors make measurements in sync with LED control. When the LED is flashed, a sensor measurement by the HiBall is triggered. Ex.1007, 10. The trigger is the data that a measurement is expected in a particular sensor's view field. *Id.*; Ex.1005 ¶70. The actual sensor measurement depends on having received the trigger, in accordance with this limitation. Ex.1007, 10; Ex.1005 ¶70.

This information is communicated via the Ceiling-HiBall Interface Board (CIB) shown in Figure 6 of Welch 2001, which a POSITA would have understood to include a "software interface" for communicating the trigger information from the LED to the HiBall sensors and for communicating the measurement information from the HiBall sensors to the Kalman filter. Ex.1007, Fig.6; Ex.1005 ¶71.

5. Claim 4: "The method of claim 3 wherein each of the software modules implements calculations that are independent of a representation of the state in the estimation subsystem."

Welch 2001 renders this limitation obvious. Ex.1005 ¶¶73-74. The individual sensors within the HiBall (each attributed to a particular Kalman filter software module) make their measurements independent of the overall estimation of HiBall pose (the claimed "representation of the state") by the estimation subsystem PC, which is computed from a stream of sensor measurements. *See* Ex.1007, 10-11; Ex.1005 ¶73. Thus, each Kalman filter associated with each individual sensor makes a separate calculation that is independent of the overall estimation computed by the estimation subsystem. Ex.1005 ¶73.

6. Claim 5: "The method of claim 1 wherein the state estimate characterizes an estimate of a location of the object."

Welch 2001 and Welch 1997 disclose this limitation. Ex.1005 ¶75. The HiBall system estimates and tracks a user's pose (position and orientation), which includes an estimate of location. Ex.1007, 2, 4, 10; Ex.1008, Abstract.

7. Claim 6: "The method of claim 1 wherein the state estimate characterizes configuration information for one or more sensing elements fixed to the object."

Welch 2001 and Welch 1997 render this limitation obvious as discussed for claim 1. Ex.1005 ¶¶76-77. The HiBall is an outward-looking sensing unit that is attached to the user/object being tracked. *See, e.g.*, Ex.1007, 4 ("In all of the optical systems we have developed…we have chosen what we call an *inside-looking-out*

configuration, in which the **optical sensors are on the (moving) user** and the landmarks (for instance, the LEDs) are fixed in the laboratory.") (italics in original). At the beginning of each estimation cycle, the HiBall system autocalibrates the system with respect to each LED sensing element using measured device parameters. *Id.*, 13; Ex.1008, §3.2; Ex.1005 ¶76.

8. Claim 7: "The method of claim 6 wherein the configuration information for the one or more sensing elements fixed to the object includes information related to position or orientation of said sensing elements relative to the object."

Welch 2001 and Welch 1997 render this limitation obvious. Ex.1005 ¶¶78-79. Welch 1997 explains that the SCAAT method is used for autocalibration with respect to each LED sensing element based on extrinsic parameters in the tracking system. Ex.1008 §§2.2, 2.3. These parameters include, for example, information about the geometric relationship (i.e., relative position and/or orientation) of the LED sensing elements to the tracked object. *Id.*; Ex.1005 ¶78.

9. Claim 8: "The method of claim 6 wherein the configuration information for the one or more sensing elements fixed to the object includes operational parameters for the one or more sensing elements."

Welch 2001 and Welch 1997 render this limitation obvious. Ex.1005 ¶¶80-81. The device-related parameters used by the measurement function to autocalibrate the system with respect to each LED sensing element, as described in Section XII.A.7, include the sensor's inherent electrical noise. *See* Ex.1008 §3.1 (explaining

that the tracking filter accounts for a "measurement noise vector" that "represents any random error (e.g., electrical noise) in the measurement"), §3.2. A POSITA would have understood that electrical noise is an "operational parameter[]" of the sensor because it reflects a characteristic of the sensor while in operation (Ex.1005 ¶80), and that the electrical noise vector would need to be incorporated into the autocalibration function, because it is necessary to generate accurate calibration and measurement. Ex.1005 ¶80.

10. Claim 9: "The method of claim 1 wherein the state estimate characterizes configuration information for one or more sensing elements fixed in an environment of the object."

Welch 2001 and Welch 1997 render this limitation obvious. Ex.1005 ¶¶82-83. As explained in Section XII.A.2.b, the LEDs in the HiBall system constitute sensing elements. The LEDs are "fixed in an environment of an object" because they are affixed to the ceiling in the lab where the HiBall sensors are used. Ex.1007, 8-9. Moreover, "the SCAAT approach offers the additional capability of being able to estimate the 3-D positions of the LEDs in the world concurrently with the pose of the HiBall, online, in real time." *Id.*, 13. Welch 1997 explains that the SCAAT system autocalibrates a separate state vector and covariance matrix for each LED source in the system. Ex.1008 §3.2.2; *see also* Ex.1007, 13 (summarizing SCAAT autocalibration filters for LEDs). This autocalibration data constitutes "configuration information" for each LED sensing element. Ex.1005 ¶82.

11. Claim 11

a. Claim 11[a]: "The method of claim 1 wherein repeatedly updating the state further includes: providing to the sensor subsystems information related to an expected sensor measurement; and"

Welch 2001 discloses this limitation. Ex.1005 ¶¶84-86. Welch 2001 explains that at each estimation cycle, a particular view from the sensor and a particular LED are selected by the interface between the computer, HiBall sensors, and ceiling LEDs ("Ceiling-HiBall Interface Board," or CIB). Ex.1007, 9, 13. Once the view and LED are selected, the CIB flashes the selected LED and the HiBall takes a single measurement. *Id.*, 10, 13. The measurement is compared with a prediction obtained using the HiBall 2-D sensor measurement model equation, which can be used "[f]or any ceiling LED…and HiBall view." *Id.*, 12-13. "[T]he difference (or residual) is used to update the filter state and covariance matrices using the Kalman gain matrix." *Id.*, 13.

The measurement prediction generated by the model equation constitutes an "expected sensor measurement." Ex.1005 ¶85. This calculation is performed by the computer within the system, and then is "provid[ed] to the sensor subsystem[]" (i.e., the CIB and the HiBall sensor/LED pairs) when it is compared against the actual measurement from the LED and HiBall sensor. Ex.1005 ¶85.

b. Claim 11[b]: "wherein accepting the measurement information from the sensor subsystem includes accepting information related to an actual sensor measurement."

Welch 2001 renders this limitation obvious. Ex.1005 ¶¶87-88. As explained in Section XII.A.11.a, Welch 2001 explains that the HiBall takes a measurement of the selected LED that is subsequently compared to an estimated measurement for the same view and LED to update the filter state in a "recursive prediction-correction cycle." Ex.1007, 13. The HiBall measurement is an "actual sensor measurement," and the system's comparison of an actual measurement to a measurement prediction from the model constitutes "accept[ance]" of the actual sensor measurement. Ex.1005 ¶87.

12. Claim 12: "The method of claim 11 wherein providing the information related to an expected sensor measurement includes providing information related to a relative geometric configuration of two of the sensing elements."

Welch 2001 renders this limitation obvious. Ex.1005 ¶¶89-91. Welch 2001 explains that the measurement model for the HiBall system incorporates the difference between "the position of the LED in the world" and "the position of the HiBall in the world." Ex.1007, 12. The difference between the HiBall and LED positions represents the relative locations of these sensing elements in a coordinate frame. *See id.*; Ex.1005 ¶89. Because the relative locations are defined using such coordinates, the relative difference between the LED position and the HiBall

position within a coordinate frame is a "geometric configuration" of these two "sensing elements." Ex.1005 ¶89.

Moreover, the calibrated pose of HiBall's multiple individual sensors also provides the geometric configuration of these sensors relative to each other. Ex.1007, 6-7, 9-10); Ex.1005 ¶90.

13. Claim 13: "The method of claim 12 wherein providing information related to a relative geometric configuration of the two of the sensing elements includes providing information characterizing a relative location of said sensing elements."

Welch 2001 discloses this limitation. Ex.1005 ¶¶92-93. As explained in Section XII.A.12, Welch 2001 describes a measurement model for the HiBall system that assesses the difference between "the position of the LED in the world" and "the position of the HiBall in the world." Ex.1007, 12. The relative difference in position between these two sensing elements satisfies this element, as explained for claim 12. Ex.1005 ¶92.

14. Claim 14: "The method of claim 11 wherein accepting the information related to an actual sensor measurement includes accepting information enabling the estimation subsystem to calculate a difference between the actual measurement and the expected measurement."

Welch 2001 and Welch 1997 disclose this limitation. Ex.1005 ¶¶94-95. Welch 2001 explains that the sensor measurement "is compared with a prediction obtained using equation (3), and the difference (or *residual*) is used to update the filter state

and covariance matrices using the Kalman gain matrix." Ex.1007, 13 (emphasis in original); Ex.1005 ¶94. Welch 1997 further explains that the "*residual* between the actual sensor measurement…and the predicted measurement" is computed within the SCAAT tracking algorithm. Ex.1008 §3.1.2 (emphasis in original).

15. Claim 15: "The method of claim 11 wherein accepting the information related to an actual sensor measurement includes accepting information for correlating measurements and geometric relationships between sensing elements."

Welch 2001 discloses this limitation. Ex.1005 ¶¶96-97. Welch 2001 explains that "the HiBall selects the specified LEPD and performs three measurements, one before the LED flashes, one during the LED flash, and one after the LED flash" to generate "measured sensor coordinates." Ex.1007, 10. These coordinates are then mapped with "three-space rays" to generate a camera viewing matrix, wherein each of the 26 views from the HiBall are sampled with rays throughout the field of view. *Id.* Once mapping is complete, the coordinates are "used to estimate the pose of the HiBall during operation." *Id.* The calibration measurements for the HiBall and the timing of measurements with the LED flashes constitute information about the relative distance and geometric relationship between the HiBall and LED sensing elements. Ex.1005 ¶96.

16. Claim 16: "The method of claim 15 wherein the information for correlating measurements and geometric relationships between sensing elements includes a mapping between a relative pose of the sensing elements and a sensor measurement."

Welch 2001 renders this limitation obvious. Ex.1005 ¶¶98-99. As explained in Section XII.A.15, Welch 2001 explains that the coordinate measurements generated by the HiBall and LED are used to estimate the pose of the HiBall. The calculations described in Welch 2001 map the coordinate measurements with the predicted orientation (pose) of the HiBall sensor. *See* Ex.1007, 12 (describing inputs to the 2D sensor measurement equation: "camera viewing matrix," "position of the LED in the world," "position of the HiBall in the world," and "a rotation matrix corresponding to the orientation of the HiBall in the world."). This pose calculation is a mapping from the positions of the LEDs ("relative pose of the sensing elements") and a measurement by the HiBall sensor because it is based on coordinate measurements. Ex.1005 ¶98.

17. Claim 17: "The method of claim 16 wherein the mapping between the relative pose of the sensing elements and the sensor measurement characterizes a linear mapping."

Welch 2001 renders this limitation obvious. Ex.1005 ¶¶100-101. A linear mapping can describe any geometric relationship. *Id.* ¶100. In the HiBall sensor (as in any camera), the projection of a measured point to a sensor location is a 3-D to 2-D mapping that is linear. *See* Ex.1007, 9-10; Ex.1005 ¶100. This linear relationship

is illustrated by a basic pinhole camera projection model utilized by the HiBall sensors and generally known to a POSITA. Ex.1007, 9-10 (offline calibration of the HiBall is based on "standard pinhole camera"); Ex.1005 ¶100.

18. Claim 18: "The method of claim 11 wherein accepting the information related to an actual sensor measurement includes accepting information characterizing an uncertainty in the actual measurement."

Welch 2001 and Welch 1997 render this limitation obvious. Ex.1005 ¶¶102-103. The SCAAT method incorporates an uncertainty measurement into the Kalman filter equations. *See, e.g.*, Ex.1008 §3.1.1 (explaining that the "process noise vector…is a normally-distributed zero-mean sequence that represents the uncertainty in the target state over any time interval"), §4.2 (initializing the "beacon filter error covariance matrices…to reflect 1 millimeter of uncertainty in the initial [LED] beacon positions"); Ex.1005 ¶102.

19. Claim 19: "The method of claim 18 wherein the information characterizing the uncertainty in the actual measurement includes parameters of a statistical distribution of an error of the actual measurement."

Welch 2001 and Welch 1997 render this limitation obvious. Ex.1005 ¶¶104-105. Welch 1997 explains that the process noise vector (a measure of uncertainty) is "a normally-distributed zero-mean sequence that represents the uncertainty in the target state over any time interval." Ex.1008 §3.1.1. Moreover, in applying the SCAAT method, Welch 1997 explains that "the 3D beacon positions" were

"perturbed…prior to simulations with a normally-distributed noise source with approximately 1.7 millimeters standard deviation." *Id.* §4. The normal distribution with standard deviation represents the statistical distribution of the error measurement, as required by this limitation. Ex.1005 ¶104.

20. Claim 20

a. Claim 20[a]: "The method of claim 1 wherein repeatedly updating the state further includes: selecting a pair of sensing elements for measurement; and"

Welch 2001 discloses this limitation. Ex.1005 ¶¶106-107. Welch 2001 explains that, in the HiBall system, a single view (out of 26) from the HiBall sensor is chosen and a visible LED within that view is selected, and the image-plane coordinates of the LED on the chosen sensor are computed using the camera model for the view and the LED. Ex.1007, 13, 17. The sensor and visible LED constitute a "pair of sensing elements," which then measure the image-plane coordinates of the LED.

b. Claim 20[b]: "providing an identification of the selected pair to the sensing subsystem."

Welch 2001 renders this limitation obvious. Ex.1005 ¶¶108-109. Once a particular view and LED have been chosen, as described in Section XII.A.20.a, the CIB interface is instructed to flash the LED and take a measurement. Ex.1007, 13, 17. A POSITA would understand that the flashing of the LED, in coordination with

the HiBall sensor, constitutes an "identification" of the LED-HiBall pair within the system. Ex.1005 ¶108.

21. Claim 21: "The method of claim 20 wherein selecting the pair of sensing elements includes selecting said elements according to an expected utility of a measurement associated with said elements to the updating of the state."

Welch 2001 discloses this limitation. Ex.1005 ¶¶110-111. The '632 Patent explains describes selecting a pair of sensing elements "based on an 'information gain' that represents the utility (or usefulness) of a measurement" and provides an example selecting a pair with the highest gain. Ex.1001, 19:35-37. Welch 2001 explains that the particular LED is selected "in a least-recently-used fashion to ensure a diversity of constraints." Ex.1007, 13. Selecting the LED in this manner is based on the expected utility of the measurement, because diverse constraints can generate more accurate measurements of position and orientation for the sensor. Ex.1005 ¶110.

22. Claim 22: "The method of claim 11 wherein repeatedly updating the state further includes: updating the state according to the accepted information related to an actual sensor measurement."

Welch 2001 and Welch 1997 disclose this limitation. Ex.1005 ¶¶112-113. Welch 1997 explains that the last step of the recursive SCAAT algorithm is correcting the tracker state estimate. Ex.1008 §3.1.2. The correction is based on the actual sensor measurement. *Id.* Welch 2001 also explains that the correction step in

the SCAAT algorithm is based on the actual measurement taken by the sensor in accord with the flashing LED. Ex.1007, 13.

23. Claim 24: "The method of claim 1 wherein updating the state estimate includes applying a Kalman Filter approach."

Welch 2001 discloses this limitation. Ex.1005 ¶¶114-115. Welch 2001 explains that the prediction-and-correction state estimates calculated by the HiBall system are accomplished using Kalman filters. *See* Ex.1007, 6 ("Pose estimates are maintained using a Kalman-filter-based prediction-correction approach known as *single-constraint-at-a-time (SCAAT)* tracking) (emphasis in original); *id.*, 11 ("We use a Kalman filter (Kalman, 1960) to fuse the measurements into an estimate of the HiBall *state* $\bar{x}$ (the pose of the HiBall). (emphasis in original).

24. Claim 25: "The method of claim 1 wherein each of said sensing elements comprises at least one of a sensor and a target."

Welch 2001 discloses this limitation. Ex.1005 ¶¶116-117. As shown in Figure 6 of Welch 2001, the sensing elements in the HiBall system include the HiBall sensors and source LED targets:

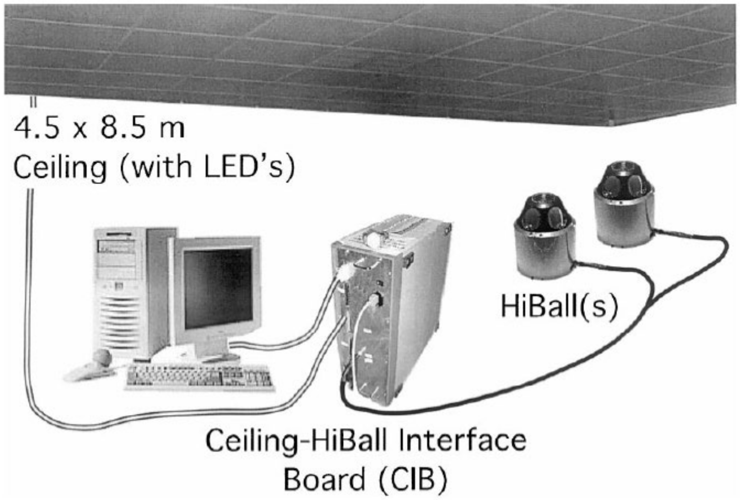


Figure 6.

Although Welch 2001 does not expressly refer to the LEDs in the HiBall system as "targets," it was well-known that the element detected by the sensor in a tracking system is a target. *See* Ex.1001, 1:21-24 ("A variety of types of sensors are available for such [tracking and navigation] systems, including sensors that measure a relative location between a sensor and a target.").

25. Claim 26: "The method of claim 25 wherein the target comprises an active device that interacts with the sensor."

Welch 2001 discloses this limitation. Ex.1005 ¶¶118-119. The '632 Patent explains that an "active target" emits signals, while a "passive target" is detectable without any signals. Ex.1001, 13:24-28. The source LEDs used with the HiBall system are "active" targets because they "are sequentially flashed (one at a time) such that they are seen via a diverse set of views for each HiBall." Ex.1007, 6. The LEDs "interact[] with the sensor" because the HiBall "performs three

measurements" in accordance with the LED flash—"one before the LED flashes, one during the LED flash, and one after the LED flash." *Id.*, 10.

26. Claim 27: "The method of claim 26 wherein the target comprises at least one of a man-made signal reflector and a natural feature of an environment."

Welch 2001 renders this limitation obvious. Ex.1005 ¶¶120-121. Welch 2001 explains that the HiBall system only uses the source LEDs, which are man-made signal reflectors, as active targets. *See* §XII.A.25. However, Welch 2001 also contemplates that the HiBall system could be "scaled indefinitely" and "evolve" to use "natural features" as targets instead of "dense active landmarks" like the LED ceiling described. Ex.1007, 4-5; Ex.1005 ¶120.

27. Claim 28: "The method of claim 1 wherein the object is selected from a group consisting of a vehicle, a robot, a person, a part of a person, a flying object, a floating object, an underwater moving object, an animal, a camera, a sensing apparatus, a helmet, a tool, a piece of sports equipment, a shoe, a boot, an article of clothing, a personal protective equipment, a rigid object having a dimension between 1 nanometer to 109 meters."

Welch 2001 discloses this limitation. Ex.1005 ¶¶122-123. In the HiBall system, the tracked object (to which the sensor is mounted) is a person, as shown in Figures 4 and 5:

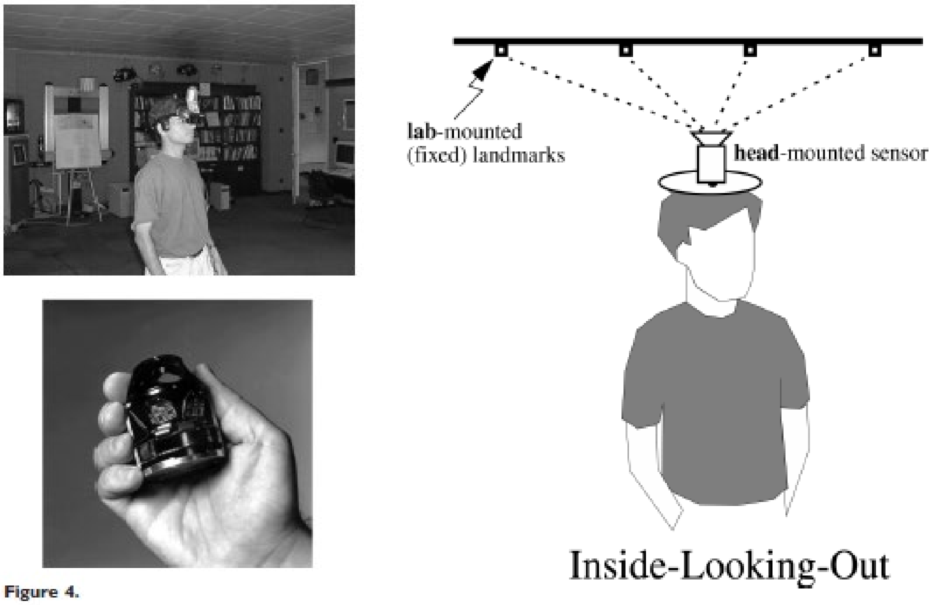


Figure 4.

28. Claim 29: "The method of claim 1 wherein the state estimate comprises information related to a position or an orientation of the object relative to a reference coordinate frame."

Welch 2001 and Welch 1997 disclose this limitation. Ex.1005 ¶¶124-125. Welch 1997 explains that in SCAAT, the state estimate for the sensor comprises information related to the target position in a reference coordinate frame using Cartesian coordinates (x, y, z), and information related to the orientation as small rotations (roll (ϕ), pitch (θ), yaw (ψ)) about the (x, y, z) axis. Ex.1008 §3.1.1; Ex.1005 ¶124.

B. <u>Ground II</u>: Claim 23 is Rendered Obvious by Welch 2001, Welch 1997, and Welch Thesis

1. Claim 23: "The method of claim 20 wherein repeatedly updating the state further includes: updating the state according to accepted measurements from inertial sensors."

Welch 2001, Welch 1997, and Welch Thesis render this limitation obvious. Ex.1005 ¶126. Welch Thesis (which Welch 2001 incorporates by reference) explains that SCAAT can be used in a hybrid tracking system that incorporates inertial sensors. *See* Ex.1009, §2.4.3 (describing use of the SCAAT algorithm in an "inertial-acoustical hybrid tracking system"); *see also id.*, §7.7. Based on this disclosure, a POSITA would have understood that the state estimates for the tracked object described in Welch 2001 could also incorporate inertial sensor measurements into the SCAAT algorithm. Ex.1005 ¶126.

C. <u>Ground III</u>: Claims 1-9, 11-24, and 28-29 are Rendered Obvious by Horton

1. Claim 1

a. Claim 1[preamble]: "A method for tracking an object comprising:"

Horton discloses a method for tracking an object in accordance with claim 1. Ex.1010, Title; 2:15-17 ("The invention is a three-dimensional position and orientation tracking system that uses accelerometers to measure acceleration in the six-degrees of freedom…"); Ex.1005 ¶127.

b. Claim 1[a]: "coupling a sensor subsystem to an estimation subsystem, said sensor subsystem enabling measurement related to relative locations or orientations of sensing elements;"

Horton renders this limitation obvious. Ex.1005 ¶¶128-130. The '632 specification explains that "[c]oupling the sensor subsystem to the estimation subsystem includes coupling software modules each associated with one or more of the sensing elements." Ex.1001, 2:50-51.

Horton's tracking system uses accelerometers to measure position and orientation of the tracked object. Ex.1010, 3:41-46. Acceleration data 35 is input to a tracking processor 40 and accelerometers 1-6 are initialized using a calibration routine 48 by loading values of pre-specified accelerometer biases. *Id.*, 5:59-6:24, Fig.3 (annotated below).

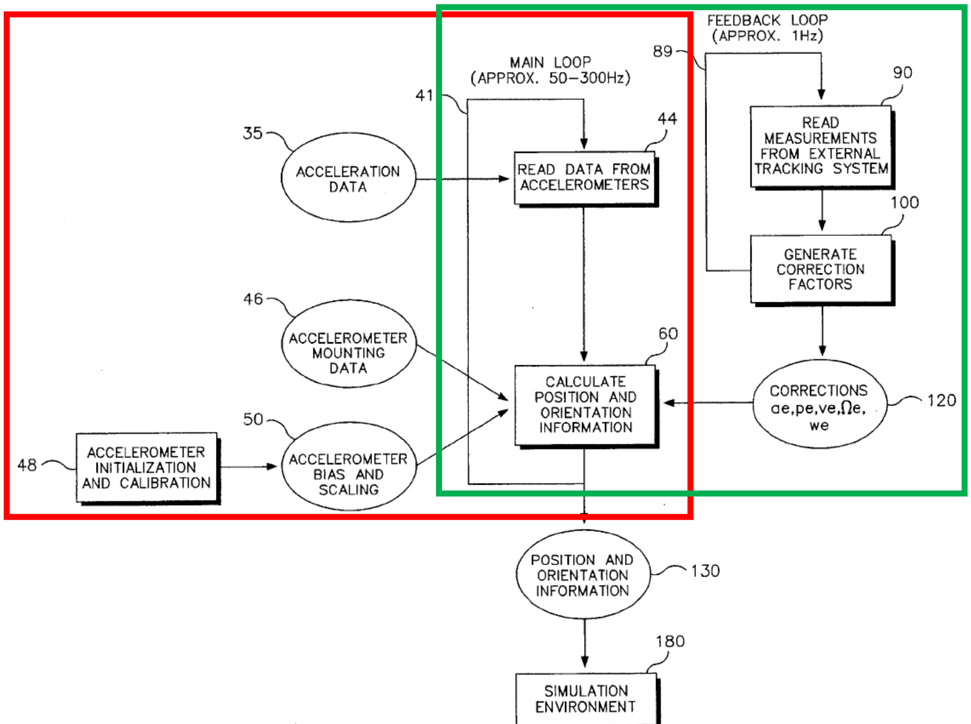


FIGURE 3

The system can also include additional external tracking sensors. *Id.*, 6:48-54.

A POSITA would have understood that **initialization routine 48** and related data constitute a **"sensor subsystem"**. Ex.1005 ¶129. The tracking system includes a tracking processor that receives information from the sensors including the accelerometers and also runs a feedback loop/Kalman filter that estimates, calculates, and corrects the position and orientation measurements from the sensors. *Id.*, 2:25-30, 41-44. A POSITA would have further understood that the **main loop 41** and the Kalman Filter (i.e., **feedback loop 89**) executed by the tracking processor 40 constitutes an **"estimation subsystem"** within the overall system because they are used for estimating the position and orientation of the tracked object. *See, e.g., id.*, 7:56-64 (describing the processor's calculation of "an estimation of position and

orientation [] one 'frame delay' into the future"); Ex.1005 ¶129. The main loop 41 couples the estimator and sensor subsystems.

c. Claim 1[b]: "accepting configuration data from the sensor subsystem;"

Horton discloses this limitation. Ex.1005 ¶¶131-133. According to Horton, "[a]ccelerometers 1-6 are initialized 48 by loading the values of the accelerometer biases [50] which are pre-specified at the factory or obtained from accelerometer specifications." Ex.1010, 5:64-67. Further, Horton teaches that mounting data 46 for each of the accelerometers 1-6 is used to determine correction factors 120 when calculating position and orientation information of the tracked object. *Id.*, 6:34-42.

Horton explains that the accelerometers are calibrated by collecting position and orientation data while the tracked object is stationary, and this data is then incorporated by the tracking processor Kalman filter. Ex.1010, 5:64-6:11. The data collected in this calibration process (Fig.3, data 46 and 50) constitutes "configuration data" within the context of this limitation.

d. Claim 1[c]: "configuring the estimation system according to the accepted configuration data;"

Horton renders this limitation obvious. Ex.1005 ¶¶134-135. Horton explains that the tracking processor compares the position and orientation data 130 from the accelerometer calibration with known measurements "and uses discrepancies between the two measurements to solve for bias and scaling factors [] for each accelerometer." Ex.1010, 6:5-11, Fig.3. The main loop 41 is then repeated multiple times to calibrate the system. *Id.*, 6:11-13, Fig.3. A POSITA would have understood that this calibration of the tracking processor is completed "according to the accepted configuration data" from the sensor calibration process.

e. Claim 1[d]: "repeatedly updating a state estimate, including accepting measurement information from the sensor subsystem, and updating the state estimate according to the accepted configuration data and the accepted measurement data."

Horton teaches this limitation. Ex.1005 ¶¶136-137. "In main loop 41[,] tracking processor 40 reads **acceleration data 35** from [the **sensor subsystem]** and calculates 60 position and orientation information 130." Ex.1010, 6:25-27. This process entails "repeatedly updating" the estimate of position and orientation for the tracked object using new measurement data from the sensor and accepted, known measurements from the calibration process. *Id.*, 5:64-6:11.

If a tracked object 300 (e.g., an HMD) is confined to a small volume (e.g., seated), then Horton teaches that "certain 'software specification' information … in

simulation environment 180 can be used in place of [external] measurements 90 as input to generation 100 of correction factors 120." *Id.*, 6:58-62. "After incorporating correction factors 120 from feedback filter loop 89, the output of calculation 60 is position and orientation information 130." *Id.*, 7:1-5.

2. Claim 2: "The method of claim 1 wherein coupling the sensor subsystem to the estimation subsystem includes coupling software modules each associated with one or more of the sensing elements."

Horton renders this limitation obvious. Ex.1005 ¶¶138-141. Main loop 41 in Horton couples the **estimation subsystem** to the **sensor subsystem**, as shown in Fig.3.

Fig.4 of Horton is a flow chart detailing the steps of main loop 41. According to Fig.4, "tracking processor 40 reads [] acceleration data 35 from each accelerometer 1-6" via multiplexer 20. *Id.*, 7:6-7. A POSITA therefore would have understood that the main loop 41 of the sensor subsystem includes coupling software modules associated with each accelerometer. Ex.1005 ¶140.

3. Claim 3: "The method of claim 2 wherein each of the software modules provides a software interface for receiving information related to an expected sensor measurement and providing measurement information that depends on said received information."

Horton renders this limitation obvious. Ex.1005 ¶¶142-143. The '632 specification indicates that information related to an expected sensor measurement

includes "information related to a relative geometric configuration of two of the sensing elements." Ex.1001, 3:16-24.

In Horton, feedback filter loop 89 (the claimed "software interface") incorporates correction factors 120 (such as accelerometer mounting data) in order to calculate position and orientation information 130. Ex.1010, 7:1-14. Fig.3, Fig.4. The accelerometer mounting information 46 comprises information in a matrix J which resolves net linear accelerations into linear body and angular components. *Id.*, 5:37-51. The elements of the matrix J are defined by locations and directions of the mounted accelerometers (the "information related to an expected sensor measurement"), as shown in Table 1. *Id.,* 5:37-51; Ex.1005 ¶142.

TABLE 1

CONSTANTS - MAIN LOOP

Symbol	Dimension	Description
T	Scalar	Update period for main loop. 0.01 seconds
T_D	Scalar	Update rate of simulation software. Typ. 1/30 sec.
B	N/A	Body or helmet coordinate frame
L	N/A	Room or chair coordinate frame. Also referred to as Level or Reference frame.
i	Scalar	1,2, . . . , 6 accelerometer number . . . see schematic
J	6 × 6	Matrix that separates corrected accelerometer readings into linear and angular components. Elements value defined from locations and directions accelerometers are mounted.
r(i)	3 × 1	Radius vector that points from origin of body frame to sensor. Measured in body frame coordinates
u(i)	3 × 1	Unit vector in direction of sensitive axis of 'i'th accelerometer. Measured in body frame coordinates
T	N/A	Transpose operator. Converts column vector to row vector
sf(i)	Scalar	Scale factor. Value converts the voltage read from the A/D converter into acceleration in m/s^2

4. Claim 4: "The method of claim 3 wherein each of the software modules implements calculations that are independent of a representation of the state in the estimation subsystem."

Horton renders this limitation obvious. Ex.1005 ¶¶144-145. During calibration, the position and orientation of the stationary tracked object are calculated by the tracking processor. *See* Ex.1010, Fig.3, 5:64-6:5. This calculation is performed separately from and without reference to the known position and orientation measurement for the accelerometer, so that the known measurement can be compared to the calculated measurement. *See id.*, 6:5-11; Ex.1005 ¶144.

5. Claim 5: "The method of claim 1 wherein the state estimate characterizes an estimate of a location of the object."

Horton renders this limitation obvious. Ex.1005 ¶¶146-147. The accelerometers are mounted to an object to be tracked, such as on a head-mounted display unit or a wristband/data glove, and thus estimate the location of the object during the calibration process. Ex.1010, 5:7-13; Ex.1005 ¶146.

6. Claim 6: "The method of claim 1 wherein the state estimate characterizes configuration information for one or more sensing elements fixed to the object."

Horton discloses this limitation. Ex.1005 ¶¶148-149. As explained in Sections XII.C.1.d and XII.C.1.e, the estimates of position and orientation calculated by the Kalman filters for the accelerometers are used to calibrate the accelerometers before tracking, such that the estimates constitute configuration (calibration) information. The accelerometers are sensing elements fixed to the tracked object. Ex.1010, 5:7-13.

7. Claim 7: "The method of claim 6 wherein the configuration information for the one or more sensing elements fixed to the object includes information related to position or orientation of said sensing elements relative to the object."

Horton discloses this limitation. Ex.1005 ¶¶150-151. The configuration information for the accelerometers, which are mounted to the tracked object, relates to the position and orientation of the accelerometer while the object is stationary. Ex.1010, 5:7-13, 5:64-6:5. The configuration process is used "to correct for the bias and scaling factors of the accelerometers" (*id.*, 5:60-64), which include position and

orientation information for the accelerometer relative to the tracked object. The calibration process corrects these factors such that the position and orientation of the accelerometers reflects the position and orientation of the tracked object. *Id.*

8. Claim 8: "The method of claim 6 wherein the configuration information for the one or more sensing elements fixed to the object includes operational parameters for the one or more sensing elements."

Horton renders this limitation obvious. Ex.1005 ¶¶152-153. Horton explains that the comparison between the calculated position and orientation measurements and known position and orientation measurements "uses discrepancies between the two measurements to solve for bias and scaling factors [] for each accelerometer." Ex.1010, 6:5-11. A POSITA would have understood that the "bias and scaling factors" are "operational parameters" for the accelerometers because they reflect inherent characteristics of the accelerometers, and that the configuration information evaluated by the Kalman filters for the accelerometers includes these parameters to calibrate the accelerometers for use. Ex.1005 ¶152.

9. Claim 9: "The method of claim 1 wherein the state estimate characterizes configuration information for one or more sensing elements fixed in an environment of the object."

Horton renders this limitation obvious. Ex.1005 ¶¶154-155. Horton explains that a calibration (configuration) process is performed by the accelerometers by collecting position and orientation data while the tracked object is stationary. Ex.1010, 5:66-6:11. The data collected in this calibration process (Fig.3, data 46 and

50) constitutes a state estimate that characterizes "configuration information." Moreover, the state estimate configuration information includes accelerometer mounting data 46, which comprises information in matrix J that is defined by the locations and directions of the mounted accelerometers. *Id.*, 5:37-51, 7:6-14, Table 1. A POSITA would have understood that the "mounted" accelerometers can be fixed in an environment of the object during the calibration (configuration) process. Ex.1005 ¶154.

10. Claim 11

a. Claim 11[a]: "The method of claim 1 wherein repeatedly updating the state further includes: providing to the sensor subsystems information related to an expected sensor measurement; and"

Horton renders this limitation obvious. Ex.1005 ¶¶156-157. Horton explains that the tracking processor uses known position and orientation measurements (i.e., expected measurements for the sensor) compared to calculated position and orientation measurements to calibrate the accelerometers. Ex.1010, 6:5-11; Ex.1005 ¶156.

b. Claim 11[b]: "wherein accepting the measurement information from the sensor subsystem includes accepting information related to an actual sensor measurement."

Horton discloses this limitation. Ex.1005 ¶¶158-159. During calibration, the accelerometers collect data for the tracked object while it is stationary, and the

tracking processor accepts and uses that data to calculate position and orientation, as shown in Figure 3:

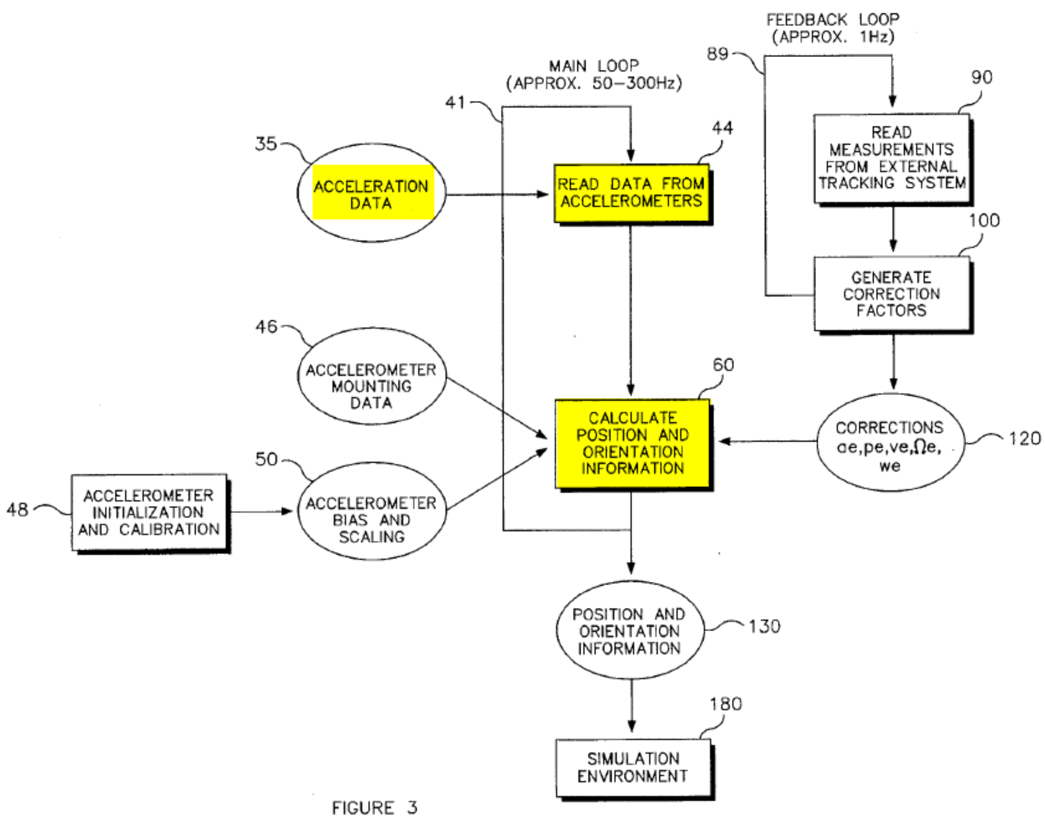


FIGURE 3

Ex.1010, Fig.3 (annotated), 5:64-6:5. The data from the accelerometers constitutes "information related to an actual sensor measurement."

11. Claim 12: "The method of claim 11 wherein providing the information related to an expected sensor measurement includes providing information related to a relative geometric configuration of two of the sensing elements."

Horton renders this limitation obvious. Ex.1005 ¶¶160-161. As explained in Section XII.C.3, one of the correction factors used to calculate position and orientation information is accelerometer mounting data, and the locations and

directions of the mounted accelerometers are defined in matrix J. Ex.1010, 5:37-51. Ex.1010, Fig.3, Fig.4, 7:6-14. These locations and directions for the accelerometers also constitute "information related to a relative geometric configuration of two of the sensing elements." Ex.1005 ¶160.

12. Claim 13: "The method of claim 12 wherein providing information related to a relative geometric configuration of the two of the sensing elements includes providing information characterizing a relative location of said sensing elements."

Horton renders this limitation obvious. Ex.1005 ¶162. As explained in Section XII.C.11, the accelerometer mounting information used as a correction factor is defined in part by the location of the accelerometers relative to each other.

13. Claim 14: "The method of claim 11 wherein accepting the information related to an actual sensor measurement includes accepting information enabling the estimation subsystem to calculate a difference between the actual measurement and the expected measurement."

Horton discloses this limitation. Ex.1005 ¶¶163-164. As noted above, the Kalman filter loop performed by the tracking processor "compares calculated position and/or orientation measurements [] with the known position and/or orientation measurement (known to be stationary) and uses discrepancies between the two measurements to solve for bias and scaling factors [] for each accelerometer." Ex.1010, 6:5-11.

14. Claim 15: "The method of claim 11 wherein accepting the information related to an actual sensor measurement includes accepting information for correlating measurements and geometric relationships between sensing elements."

Horton renders this limitation obvious. Ex.1005 ¶¶165-166. As explained in Section XII.C.3, because accelerometer mounting data is one of the correction factors used for updating and correcting position and orientation measurements, a POSITA would have understood that the information "accepted" by the system relates to "correlating measurements and geometric relationships between sensing elements." Ex.1005 ¶165.

15. Claim 16: "The method of claim 15 wherein the information for correlating measurements and geometric relationships between sensing elements includes a mapping between a relative pose of the sensing elements and a sensor measurement."

Horton renders this limitation obvious. Ex.1005 ¶¶167-168. One embodiment described in Horton describes mounting six accelerometers in two groups of three that are each orthogonal (i.e. at right angles). Ex.1010, 5:57-58. When the accelerometers are placed in this manner, the accelerometer mounting data described in Section XII.C.3 includes a mapping between the relative pose of the sensing elements (i.e., their orthogonal placement) and a sensor measurement. Ex.1005 ¶167.

16. Claim 17: "The method of claim 16 wherein the mapping between the relative pose of the sensing elements and the sensor measurement characterizes a linear mapping."

Horton renders this limitation obvious. Ex.1005 ¶169-170. A linear mapping can describe any geometric relationship. Ex.1005 ¶169. For the orthogonally-mounted accelerometers described in Section XII.C.15, the mapping of the accelerometer mounting data described in Section XII.C.3 would be a linear mapping. Ex.1005 ¶169.

17. Claim 18: "The method of claim 11 wherein accepting the information related to an actual sensor measurement includes accepting information characterizing an uncertainty in the actual measurement."

Horton renders this limitation obvious. Ex.1005 ¶¶171-172. The calculation of correction factors for run time measurements includes updating a process noise matrix (represented at 104 in Figure 5 below), which "is the expectation of the dot product of the vectors that represent the noise of each element in the state vector of the system." Ex.1010, 8:20-28, Fig.5, Table 4.

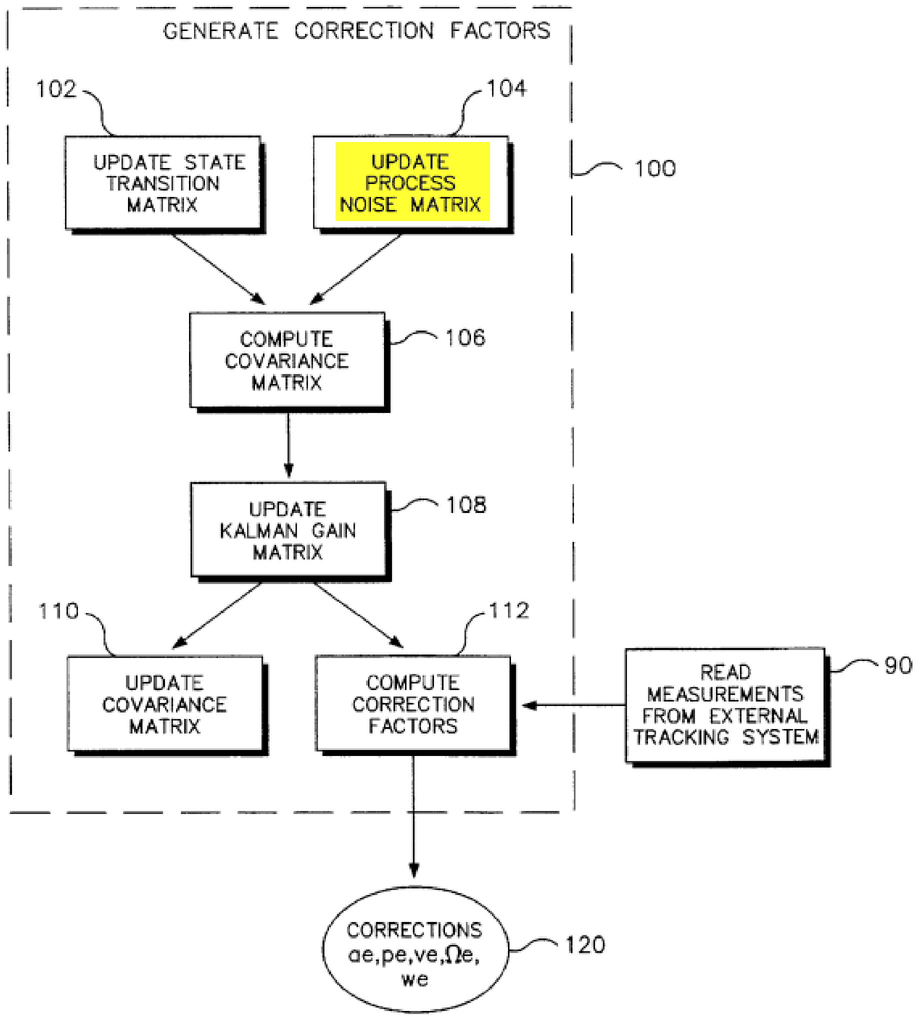


FIGURE 5

See also id., 8:38-53. This noise data represents an uncertainty associated with sensor measurements. Ex.1005 ¶171.

18. Claim 19: "The method of claim 18 wherein the information characterizing the uncertainty in the actual measurement includes parameters of a statistical distribution of an error of the actual measurement."

Horton renders this limitation obvious. Ex.1005 ¶¶173-174. A POSITA would have understood that the process noise matrix described in Section XII.C.17 would

be related to a statistical distribution of error for a measurement, characterized by noise. Ex.1005 ¶173. A matrix calculation, such as that described in Horton, would be used to determine such a statistical distribution of error for the measurement. *Id.*

19. Claim 20

a. Claim 20[a]: "The method of claim 1 wherein repeatedly updating the state further includes: selecting a pair of sensing elements for measurement; and"

Horton discloses this limitation. Ex.1005 ¶¶175-177. The system described in Horton can include optical tracking sensors. Ex.1010, 6:48-54, cl. 9. A POSITA would have understood that an optical tracker would necessarily utilize a pair of sensing elements (i.e., a camera and a target) for measurement of position and orientation because the camera needs to detect a target in order to generate an image for a measurement calculation. Ex.1005 ¶175.

Horton also explains that two accelerometers can be selected to track an object in one-dimensional space. Ex.1010, 3:49-51. Limiting the measurement to one dimension and two accelerometers also constitutes "selecting a pair of sensing elements for measurement."

b. Claim 20[b]: "providing an identification of the selected pair to the sensing subsystem."

Horton discloses this limitation. Ex.1005 ¶¶178-179. The generation of position and orientation information by an external tracking system with two sensing elements necessarily identifies the pair of sensing elements, because both sensing

elements are needed to generate a measurement (i.e. a camera and a target in an optical system). Ex.1005 ¶178. Additionally, the use of only two accelerometers within the system to track the object in one dimension would require the system to identify the particular two accelerometers to be used for that purpose. *See* Ex.1010, 3:49-51; Ex.1005 ¶178.

20. Claim 21: "The method of claim 20 wherein selecting the pair of sensing elements includes selecting said elements according to an expected utility of a measurement associated with said elements to the updating of the state."

Horton discloses this limitation. Ex.1005 ¶¶180-181. The '632 Patent explains that a pair of sensing elements are selected "based on an 'information gain' that represents the utility (or usefulness) of a measurement by the pair of" sensing elements. Ex.1001, 19:35-37. Horton explains that the selection of two accelerometers in the system would be used to track the object in one-dimensional space. Ex.1010, 3:49-51. Thus, the "expected utility" (usefulness) of measurement from these two sensors would be for one-dimensional tracking (i.e., updating the state) of the object as it moves. Ex.1005 ¶180.

21. Claim 22: "The method of claim 11 wherein repeatedly updating the state further includes: updating the state according to the accepted information related to an actual sensor measurement."

Horton discloses this limitation. Ex.1005 ¶¶182-183. During calibration, the accelerometers collect data for the tracked object while it is stationary, and the

tracking processor accepts and uses that data to calculate position and orientation, as shown in Figure 3:

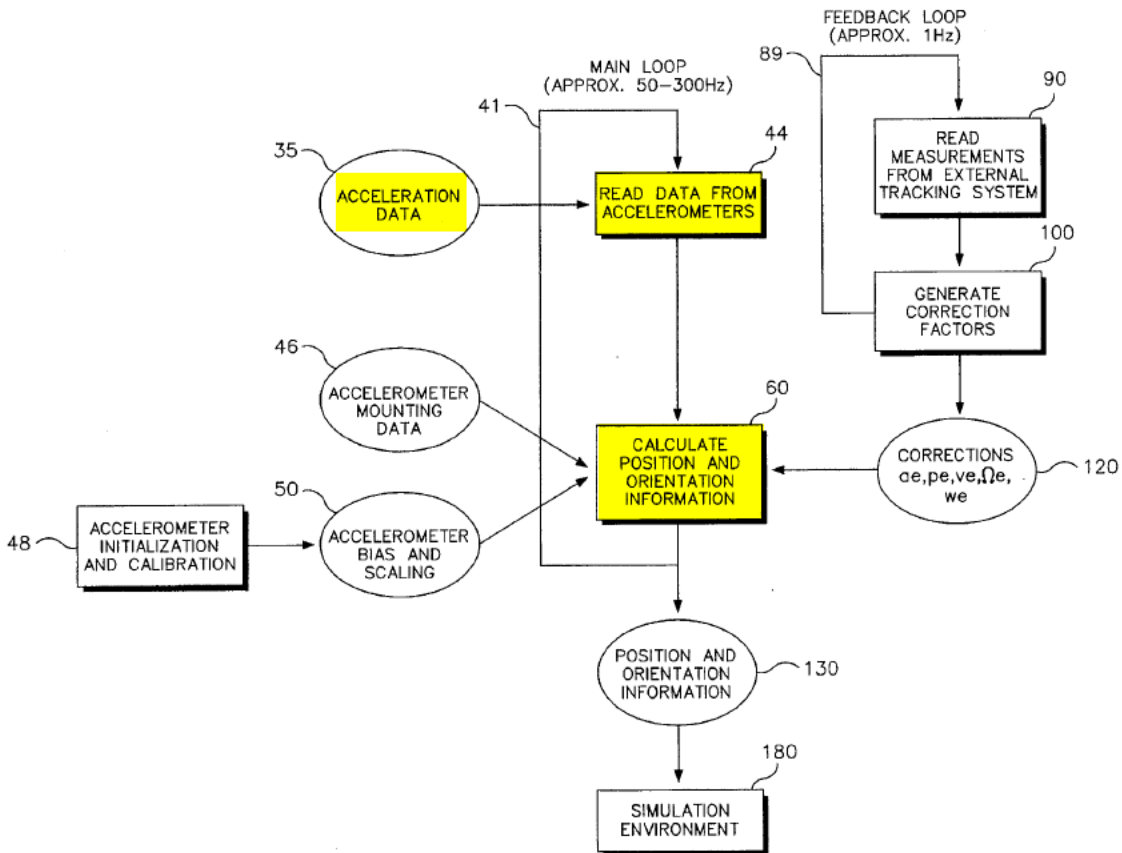


FIGURE 3

Ex.1010, Fig.3 (annotated), 5:64-6:5. The data from the accelerometers, which constitutes "information related to an actual sensor measurement," is used to update the position and orientation estimate for the tracked object via the main loop. *See* §§XII.C.1.d, XII.C.1.e.

22. Claim 23: "The method of claim 20 wherein repeatedly updating the state further includes: updating the state according to accepted measurements from inertial sensors."

Horton renders this limitation obvious. Ex.1005 ¶¶184-185. As explained throughout this section, Horton explains that accelerometers (which are inertial sensors) can be used to correct and update the position and orientation estimates for the tracked object. Ex.1005 ¶¶184.

23. Claim 24: "The method of claim 1 wherein updating the state estimate includes applying a Kalman Filter approach."

Horton discloses this limitation. Ex.1005 ¶¶186-187. Horton explains that the feedback filter loop used to correct and update the position and orientation estimates for the tracked object is a Kalman filter. *See* Ex.1010, 6:34-39 ("Feedback loop 89 (also known as a Kalman filter) comprises reading tracking measurements 90 (e.g., position, orientation, and/or velocity) from external tracking system 170 (FIGS. 6, 7) disposed relative to object 300 and generating 100 correction factors 120."); *id.*, 2:41-44.

24. Claim 28: "The method of claim 1 wherein the object is selected from a group consisting of a vehicle, a robot, a person, a part of a person, a flying object, a floating object, an underwater moving object, an animal, a camera, a sensing apparatus, a helmet, a tool, a piece of sports equipment, a shoe, a boot, an article of clothing, a personal protective equipment, a rigid object having a dimension between 1 nanometer to 109 meters."

Horton discloses this limitation. Ex.1005 ¶188. Horton explains that the tracked object can be implemented on, for example, a "head-mounted display unit,

a wristband/data glove, or other similar device attached to a user to monitor the user's movement." Ex.1010, 5:10-13.

25. Claim 29: "The method of claim 1 wherein the state estimate comprises information related to a position or an orientation of the object relative to a reference coordinate frame."

Horton discloses this limitation. Ex.1005 ¶¶189-190. Horton explains that the tracking system measures position and orientation "in the six-degrees of freedom (e.g., x, y, z position coordinates and roll, pitch, yaw orientation components) of a moveable object," which is related to a reference coordinate frame. Ex.1010, 2:15-20; *see also id.*, 4:47-50; Ex.1005 ¶189. The six-degree of freedom measurement is based on a reference coordinate frame. Ex.1005 ¶189. Horton also explains that position and orientation information "is reported in a fixed, or level frame reference defined by X_L, Y_L, Z_L" and that a level frame reference is a "coordinate system." *Id.*, 5:31-35.

D. <u>Ground IV</u>: Claims 25-27 are Rendered Obvious by Horton in View of Welch 1997

1. Motivation to Combine

A POSITA would have been motivated to combine Horton with Welch 1997 because both references disclose technologies and calculation methods related to estimating and tracking position and orientation of an object. *See* Ex.1010, Abstract; Ex.1008, Abstract. Both references are directed to the same technological field and solution. Ex.1005 ¶191. Horton also expressly discloses the use of a "conventional"

"external tracking system," such as an optical tracking system, with the claimed tracking method to generate position and orientation data for the tracked object. Ex.1010, 6:48-51. Welch 1997 also discloses that such tracking systems, such as camera-based optical tracking systems, were generally known. *See* Ex.1008 §1.2.

Horton further explains that external tracking systems are useful, for example, "[i]f the volume in which object 300 moves is relatively large compared to the size of object." Ex.1010, 6:43-44. Consequently, a POSITA would have been motivated to use the camera-based system described in Welch 1997 as the external tracking system with Horton as it is specifically used as a "wide area" tracking system in a larger space. *See* Ex.1008 §§2.1, 4.

2. Claim 25: "The method of claim 1 wherein each of said sensing elements comprises at least one of a sensor and a target."

Horton in view of Welch 1997 renders this limitation obvious. Ex.1005 ¶¶192-194. The "conventional" external tracking systems used in addition to the accelerometers can include "for example, radar, sonar, infrared, optical, acoustic/ultrasonic, or magnetic tracking technology." Ex.1010, 6:48-51. A POSITA also would have understood that an optical tracking system was a well-known external tracking system at the priority date of the '632 Patent as shown by Welch 1997. *See* Section XII.A.24. A POSITA would have understood that Welch 1997's

optical sensor-target tracking systems could have been used in Horton. Ex.1005 ¶¶192-193.; *see* Section XII.D.1.

3. Claim 26: "The method of claim 25 wherein the target comprises an active device that interacts with the sensor."

Horton in view of Welch 1997 renders this limitation obvious. Ex.1005 ¶¶195-196. A POSITA would have understood that the tracking system using these "active" targets in Welch 1997 (*see* Section XII.A.25) could have been used as the external tracking system described in Horton. Ex.1005 ¶195.

4. Claim 27: "The method of claim 26 wherein the target comprises at least one of a man-made signal reflector and a natural feature of an environment."

Horton in view of Welch 1997 renders this limitation obvious. *See* Section XII.A.26; Ex.1005 ¶¶197-198.

E. <u>Ground V</u>: Claims 66-68 Are Rendered Obvious by Kramer in View of Chen

1. Motivation to Combine

Kramer describes tracking the position of an object using multiple sensing technologies: optical tracking and electromagnetic tracking. Ex.1030, Abstract, 1:18-20. Kramer states that position information from the combination provides a more reliable, accurate, and/or less delayed measurement system than any tracking methods taken separately. *Id.*, 2:63-3:1. Kramer further recognized that various sensors (e.g., magnetic or inertial sensors) could be used in conjunction with the optical tracker to correct the optical tracker's faults. *Id.*, 8:61-64.

Kramer also describes using Kalman filtering to produce an accurate estimate of the position/orientation of the tracked object. *Id.*, 5:51-54; Ex.1005 ¶201. Kramer indicates that estimator algorithms like the Kalman filter can be implemented on a data processor, but does not explicitly describe how sensor information utilized by the Kalman algorithm is obtained by the processor. *Id.*

Chen describes how analog transducers such as the sensors employed by Kramer communicate digital information for self-identification and configuration to interface with legacy data acquisition systems. Ex.1024, 24-25. Chen explains that the IEEE P1451.4 Transducer Electronic Data Sheet ("TEDS") standard would enable transducers to have plug and play functionality and communicate relevant information, including identification parameters, device parameters (e.g., sensor type and sensitivity), calibration parameters, and application parameters. *Id.* Upon powering up or interrogation, a P1451.4 sensor would enter a digital communication mode. In a legacy system, an embedded controller or software would extract the TEDS data from the sensor. The Chen solution required no modification of legacy systems, nor additional hardware.

A POSITA would have been motivated to update Kramer's data processor to interface with a set of sensors having a TEDS. First, this combination would provide standard compliance, a strong motivator for a POSITA. Ex.1005 ¶203. A POSITA would have recognized that sensors complying with the IEEE standard will perform

and sell better than those that are not compliant, due to the interoperability of components. *Id.* A POSITA would have had a reasonable expectation of success, because, as explained by Chen, legacy systems such as the system described by Kramer could support a P1451.4 transducer without modification or additional hardware. *Id.*

2. Claim 66

a. Claim 66[preamble]: "A method comprising:"

Kramer discloses this limitation. Ex.1005 ¶204. Kramer is directed to a method for reporting movement of an object "using combinations of sensors, where the deficiency of one may be compensated for by the proficiency of the other." Ex.1030, 20:23-25.

b. Claim 66[a]: "receiving sensor configuration information indicating a set of sensing elements available to a tracking or navigation system;"

Kramer in view of Chen renders obvious this limitation. Ex.1005 ¶205. For example, Chen teaches that an analog transducers such as the sensors employed by Kramer would communicate digital information for the purposes of self-identification and configuration upon powering up or interrogation. Ex.1024, 26. In use with a legacy system such as that described in Kramer, an embedded controller or software would extract the TEDS data from the sensors. *Id.*

c. Claim 66[b]: "configuring a data processing module of the tracking or navigation system based on the sensor configuration information"

Kramer discloses this limitation. Ex.1005 ¶¶206-207. For example, Kramer describes an embodiment with various types of sensors distributed about a golfer's body and equipment. Ex.1030, Fig.2, 14:58-67. The information from these sensors is sent to a data processor to configure the processor to calculate estimated position of the body parts: "The data processor receives the spatial placement information from each pair of 6-DOF-E and 6-DOF-A sensors, performs the necessary mathematical manipulations and calculations, and produces the corrected spatial placement information of the associated forearm." *Id.*, 17:16-19.

Kramer also describes using the sensor information with commonly known techniques, such as Kalman filtering, to track an object. Ex.1030, 5:51-57. Kalman filtering incorporates knowledge of the sensing devices, among other parameters, to produce an accurate estimate of the position/orientation of the tracked object (e.g., a body part). *See* Ex.1005 ¶207. Kramer indicates that pose estimation algorithms such as Kalman filtering can be implemented on a data processor. Ex.1030, 5:63-64.

i. Claim 66[b-1]: "to selectively perform one of (a) receiving data from at least one inside-out bearing sensor, and updating an estimated pose of an object based on data received from the inside-out bearing sensor,"

Kramer in view of Chen renders obvious this limitation. Ex.1005 ¶¶208-209. The ’632 Patent describes “bearing sensors” as including “laser scanners, linear CCD (charge coupled device) sensors, and phased array sensors,” along with “imaging sensors, PSD (position sensitive device) sensors, quadcells, and pan/tilt servos.” Ex.1001, 14:20-25, 23:53-54; Ex.1005 ¶208.

Kramer discloses using electromagnetic sensors where the transmitter (272) is fixed away from the user, *i.e.*, in the environment, in an inside-out configuration consisting of a number of electromagnetic sensors affixed to the user (236, 242, 244, 250, 252).

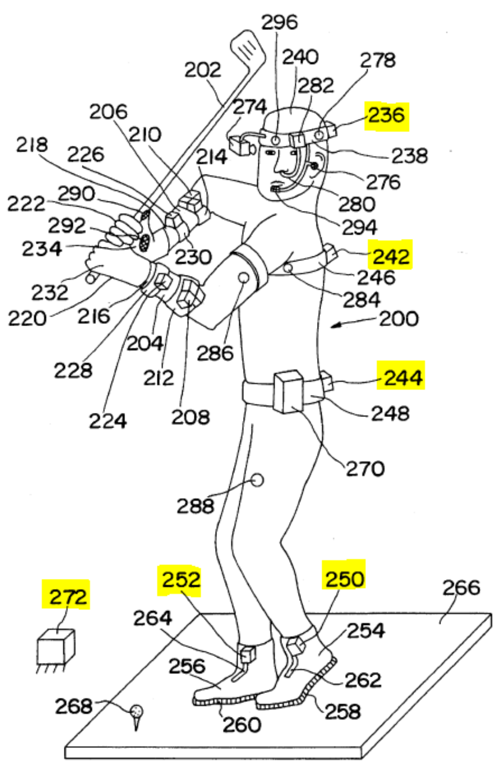
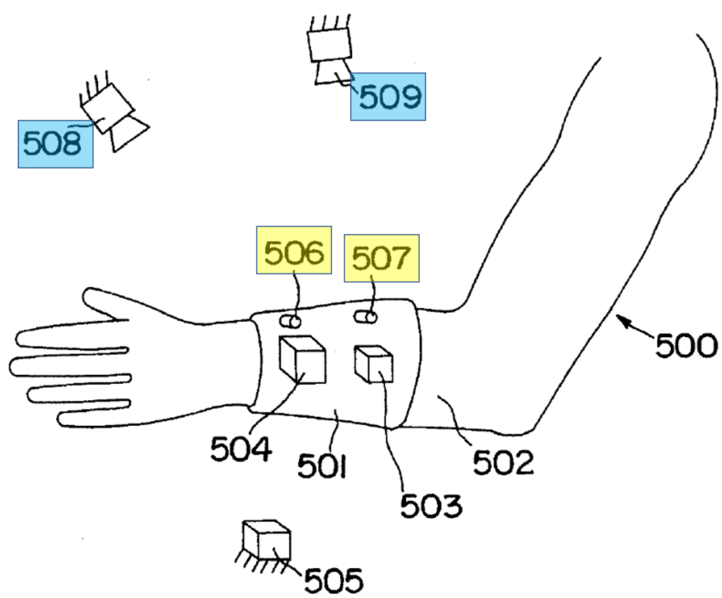


FIG. 2

Ex.1030, Fig.2.

ii. Claim 66[b-2]: "[to selectively perform one of] (b) receiving data from at least one outside-in bearing sensor, and updating an estimated pose of an object based on data received from the outside-in bearing sensor, and"

Kramer in view of Chen renders obvious this limitation. Ex.1005 ¶210. Kramer teaches using alternate sensors, such as an electromagnetic sensor and/or accelerometer, to compensate for an optical tracker's signal in the event of, e.g., occlusion of the optical tracker. Ex.1030, 8:61-9:23; Ex.1005 ¶210. Kramer discloses an arm-mounted optical tracking system with light sources (506, 507) affixed to the user's arm. *Id.*, 18:35-45. Light sensors (508, 509), which may be CCD cameras, are located away from the user's arm and sense the light emitted by the light sources 506 and 507. *Id.* This is an outside-in sensor configuration.



Ex.1030, Fig.5 (highlighting light sources in yellow and light sensors in blue); Ex.1005 ¶210.

d. Claim 66[b-3]: "[to selectively perform one of] (c) receiving data from at least one inside-out bearing sensor and at least one outside-in bearing sensor, and updating an estimated pose of an object based on data received from the outside-in bearing sensor and the inside-out bearing sensor."

Kramer in view of Chen renders obvious this limitation. Ex.1005 ¶211. Kramer teaches that an updated pose estimation can be obtained using data received from both the optical sensor—when it is not occluded—and the electromagnetic sensor. *See, e.g.*, Ex.1030. 5:51-67, 8:61-9:23, 19:10-26; Ex.1005 ¶211. Kramer therefore teaches that an updated pose estimation can be obtained using both the inside-out and outside-in sensors. *Id.*

3. Claim 67: "The method of claim 66 further comprising configuring the data processing module to selectively perform one of"

As discussed above, Kramer in view of Chen renders obvious the method of claim 66.

a. "(d) receiving data from at least one range sensor, and updating an estimated pose of an object based on data received from the range sensor,"

Kramer in view of Chen renders obvious this limitation. Ex.1005 ¶213. For example, Kramer teaches that its system may use an ultrasonic sensor or GPS sensor as a "slow" sensor. Ex.1030, 7:36-46. The '632 Patent identifies ultrasonic and GPS sensors as range sensors. Ex.1001, 14:18-20. Data received from the ultrasonic

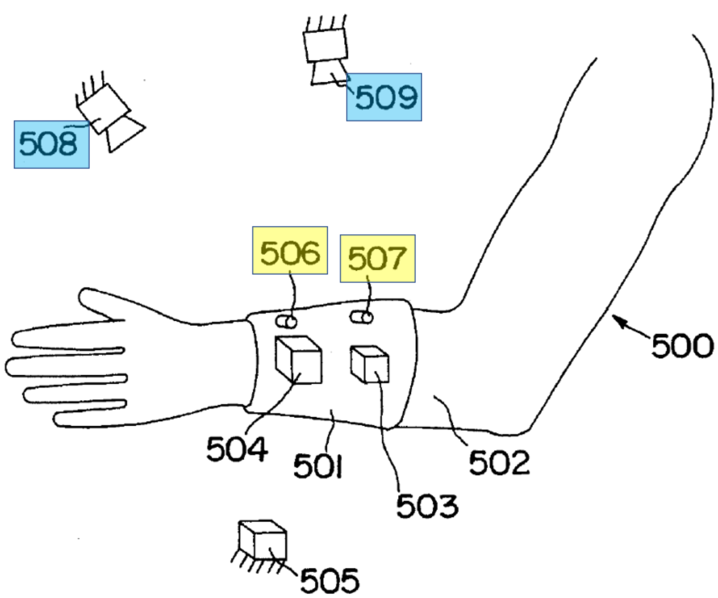
sensor can be used to calculate an updated pose estimate. *See, e.g.*, *id.*, 2:63-3:28; Ex.1005 ¶213.

b. "(e) receiving data from at least one range sensor and at least one inside-out bearing sensor, and updating an estimated pose of an object based on data received from the range sensor and the inside-out bearing sensor,"

Kramer in view of Chen renders obvious this limitation. Ex.1005 ¶¶214-215. Kramer discloses the use of electromagnetic sensors in an inside-out configuration. *See* Section XII.E.2.c.i,, *supra*. Kramer also discloses using a ranging sensor, e.g., an ultrasonic sensor, as a "slow" position sensor. *See* Ex.1030, 7:36-43. Kramer contemplates the use of two "slow" sensors together: a combination of a delayed sensor (e.g., electromagnetic sensor) with an optical tracker to compensate for defects in the optical tracker due to, e.g., occlusions. *See id.*, 9:5-13. Kramer also describes using other position sensors, including electromagnetic and/or ultrasonic sensors. Ex.1030, 7:36-43. Thus, Kramer teaches that an electromagnetic sensor can be used to compensate for an ultrasonic sensor and vice versa. Ex.1005 ¶215. In either configuration, signals from the electromagnetic sensor and ultrasonic sensors update an estimated pose. *Id.*

c. "(f) receiving data from at least one range sensor and at least one outside-in bearing sensor, and updating an estimated pose of an object based on data received from the range sensor and the outside-in bearing sensor, and"

Kramer in view of Chen renders obvious this limitation. Ex.1005 ¶216. As discussed above, Kramer discloses arm-mounted optical tracking system light sources (506, 507). Ex.1030, 18:35-45. Light sensors (508, 509), which may be CCD cameras, are located away from the user's arm and sense the light emitted by the light sources 506 and 507. *Id.* This is an outside-in sensor configuration.



Ex.1030, Fig.5 (highlighting light sources in yellow and light sensors in blue added).

Kramer teaches that "a combination of fast and delayed sensors as described previously (e.g., an accelerometer and an electromagnetic sensor as a backup delayed sensor), in conjunction with the optical tracker" can be used in its system. Ex.1030, 9:5-13. This allows the advantages of the optical tracker and a "continuous

rapid signal" while also correcting for blind spots. *Id.*; Ex.1005 ¶216. Thus, Kramer contemplates a system in which the ultrasonic sensor (a "slow" sensor) may be used in conjunction with the optical tracking system. *See* Ex.1005 ¶216; Ex.1030, 7:36-46, 9:5-13.

d. "(g) receiving data from at least one range sensor, at least one outside-in bearing sensor, and at least one inside-out bearing sensor, and updating an estimated pose of an object based on data received from the range sensor, the inside-out bearing sensor, and the outside-in bearing sensor."

Kramer in view of Chen renders obvious this limitation. Ex.1005 ¶217. As discussed above, Kramer contemplates collecting data from a range sensor (e.g., an ultrasonic sensor), an outside-in bearing sensor (e.g., an optical tracker), and an inside-out bearing sensor (e.g., an electromagnetic sensor). *See, e.g.*, Ex.1030, 9:5-13. Kramer also renders obvious using the data from each of these sensors to update the estimated pose of a tracked object, such as a body part. *See, e.g.*, *id.*, 2:63-3:28, 8:61-9:23; Ex.1005 ¶217.

4. Claim 68

a. Claim 68[preamble]: "An apparatus comprising:"

Kramer discloses this limitation. Ex.1005 ¶218. As explained with respect to claim 66, Kramer discloses a device for reporting movement of an object "using combinations of sensors, where the deficiency of one may be compensated for by the proficiency of the other." Ex.1030, 20:23-26.

b. Claim 68[a]: "an estimation module to estimate a pose of an object based on measurement data from sensing elements, the estimation module configured to enable selective performance of"

Kramer in view of Chen renders obvious this limitation. Ex.1005 ¶219. Kramer describes an embodiment with various types of sensors distributed about a golfer's body and equipment. Ex.1030, Fig.2, 14:58-67. Kramer explains that "one or more previously measured sensor values and errors (for example, deviations between prior slow and fast measurements)" are used as "inputs to an estimation filter [*i.e.*, the claimed "estimation module"] which produces a prediction of the present sensor value or of the error at the present sample time." Ex.1030, 5:51-67. Kramer explains that this filter can be, *e.g.*, a Kalman filter. *Id.* A POSITA would have understood that Kalman filtering incorporates knowledge of the sensing devices, among other parameters, to produce an accurate estimate of the position/orientation of the tracked object (e.g., a body part). *See* Ex.1005 ¶219.

i. Claim 68[a-1]: "(a) receiving data from at least one inside-out bearing sensor, and updating an estimated pose of an object based on the data received from the inside-out bearing sensor,"

Kramer discloses this limitation for the same reasons discussed above with respect to claim 66.

ii. Claim 68[a-2]: "(b) receiving data from at least one outside-in bearing sensor, and updating an estimated pose of an object based on the data

received from the outside-in bearing sensor, and"

Kramer discloses this limitation for the same reasons discussed above with respect to claim 66.

iii. Claim 68[a-3]: "(c) receiving data from at least one inside-out bearing sensor and at least one outside-in bearing sensor, and updating an estimated pose of an object based on the data received from the outside-in bearing sensor and the inside-out bearing sensor."

Kramer discloses this limitation for the same reasons discussed above with respect to claim 66.

F. Ground VI: Claim 69 Is Rendered Obvious by Kramer, Chen, and Welch 2001

1. Motivation to Combine

A POSITA would have been motivated to combine Kramer and Chen for the reasons discussed with respect to Ground V.

Welch 2001 describes an autocalibration technique for ceiling-mounted LED targets (sensing elements) in an inside-out tracking system. Ex.1007 at 13. In this system, the LEDs are autocalibrated by defining a distinct Kalman filter for each LED. *Id.* at 13.

A POSITA would have been motivated to use this autocalibration technique with the inside-out electromagnetic sensor system described in Kramer to estimate the position of the receiver relative to the tracked object. Ex.1005 ¶225. Welch 2001

explains that estimating the location of the target as well as the sensor "is a tremendous benefit in terms of the accuracy and noise characteristics of the estimates," and that being able to estimate the position of the target was a known problem in the art. Ex.1007 at 13. Thus, the combination would have been predictable and obvious to try. Ex.1005 ¶225.

2. Claim 69

a. Claim 69[preamble]: "An apparatus comprising:"

Kramer in view of Chen renders this limitation obvious as discussed above for claim 66.

b. Claim 69[a]: "an estimation module to estimate a pose of an object based on measurement data from sensing elements, the estimation module configured to enable selective performance of one of:"

Kramer in view of Chen renders this limitation obvious as discussed above for claim 66.

i. Claim 69[a-1]: "(a) updating an estimate of the position or orientation of the object relative to an environment,"

Kramer in view of Chen renders this limitation obvious as discussed above for claim 66.

ii. Claim 69[a-2]: "(b) updating an estimate of the position or orientation, relative to the object, of at least one sensing element fixed to the object, and"

Kramer in view of Chen renders this limitation obvious as discussed above for claim 66.

iii. Claim 69[a-3]: "(c) updating an estimate of the position or orientation, relative to the environment, of at least one sensing element fixed in the environment."

Kramer in view of Chen and Welch 2001 renders this limitation obvious. Ex.1005 ¶230. As shown above, the transmitter (a sensing element) for the electromagnetic sensor described in Kramer is fixed in the environment. Ex.1030, Fig. 2. While Kramer does not describe estimating the position of the transmitter, a POSITA would have been motivated to perform that estimation using the target autocalibration techniques described in Welch 2001. This technique would enable estimation of the position of the transmitter in the world, relative to the environment. Ex.1007 at 13.

XIII. SECONDARY CONSIDERATIONS

Petitioner is unaware of any evidence of secondary considerations that would support a finding of non-obviousness, but no secondary considerations could overcome the strong *prima facie* case of obviousness shown in this Petition. *See Wyers v. Master Lock Co.*, 616 F.3d 1231, 1246 (Fed. Cir. 2010). Should Patent Owner attempt to meet its burden to show secondary considerations, Petitioner reserves the right to respond.

XIV. CONCLUSION

Petitioner requests institution of an IPR and cancellation of the Challenged Claims.

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CERTIFICATE OF COMPLIANCE

This Petition complies with the type-volume limitations as mandated in 37 C.F.R. §42.24, totaling 13,881 words. Counsel has relied upon the word count feature provided by Microsoft Word.

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CERTIFICATE OF SERVICE

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